UNIVERSITY OF ILLINOIS

Agricultural Experiment Station

SOIL REPORT No. 30

JOHNSON COUNTY SOILS

By R. S. SMITH, E. A. NORTON, E. E. DeTURK, F. C. BAUER, and L. H. SMITH

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The Soil Survey of Illinois was organized under the general supervision of Professor Cyril G. Hopkins, with Professor Jeremiah G. Mosier directly in charge of soil classification and mapping. After working in association on this undertaking for eighteen years, Professor Hopkins died, and Professor Mosier followed two years later. The work of these two men enters so intimately into the whole project of the Illinois Soil Survey that it is impossible to disassociate their names from the individual county reports. Therefore recognition is hereby accorded Professors Hopkins and Mosier for their contribution to the work resulting in this publication.

INTRODUCTORY NOTE

It is a matter of common observation that soils vary tremendously in their productive power, depending upon their physical condition, their chemical composition, and their biological activities. For any comprehensive plan of soil improvement looking toward the permanent maintenance of our agricultural lands, a definite knowledge of the various existing kinds or types of soil is a first essential. It is the purpose of a soil survey to classify the various kinds of soil of a given area in such a manner as to permit definite characterization for description and for mapping. With the information that such a survey affords, every farmer or landowner of the surveyed area has at hand the basis for a rational system of improvement of his land. At the same time the Experiment Station is furnished an inventory of the soils of the state, upon which intelligently to base plans for those fundamental investigations so necessary for solving the problems of practical soil improvement.

This county soil report is one of a series reporting the results of the soil survey which, when completed, will cover the state of Illinois. Each county report is intended to be as nearly complete in itself as it is practicable to make it, even at the expense of some repetition. There is presented in the form of an Appendix a general discussion of the important principles of soil fertility, in order to help the farmer and landowner to understand the significance of the data furnished by the soil survey and to make intelligent application of the same in the maintenance and improvement of the land. In many cases it will be of advantage to study the Appendix in advance of the soil report proper.

Data from experiment fields representing the more extensive types of soil, and furnishing valuable information regarding effective practices in soil management, are embodied in form of a Supplement. This Supplement should be referred to in connection with the descriptions of the respective soil types found in the body of the report.

While the authors must assume the responsibility for the presentation of this report, it should be understood that the material for the report represents the contribution of a considerable number of the present and former members of the Agronomy Department working in their respective lines of soil mapping, soil analysis, and experiment field investigation. In this connection special recognition is due the late Professor J. G. Mosier, under whose direction the soil survey of Johnson county was conducted, and to Mr. H. C. Wheeler, who was in direct charge of the field party in the construction of the map.

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JOHNSON COUNTY SOILS

By R. S. SMITH, E. A. NORTON, E. E. DeTURK, F. C. BAUER and L. H. SMITH[1]

LOCATION AND CLIMATE OF JOHNSON COUNTY

Johnson county is located in the southern part of Illinois, midway between the Ohio and Mississippi rivers and about 30 miles north of their junction. The county is practically square, embracing an area of 336 square miles.

The climate of Johnson county is characterized by a wide range between the extremes of winter and summer. According to the records of the Weather Bureau Station at New Burnside, the greatest range of temperature in any year from 1895 to 1924 was 129 degrees in 1918. The lowest temperature recorded was –26° in 1912; the highest, 112° in 1901. The average date of the last killing frost in spring is April 17; the earliest in fall, October 22. The length of the growing season therefore is about 188 days.

The average annual precipitation for the county, from 1895 to 1924, was 43.73 inches. The highest rainfall in any one year, that in 1923, was 57.64 inches; the lowest, in 1901 was 28.08 inches. The average annual rainfall by months for this period was as follows: January, 3.97 inches; February, 2.76; March, 4.39; April, 4.45; May, 4.03; June, 3.47; July, 3.68; August, 3.47; September, 3.18; October, 3.07; November, 3.22; December, 3.65. The proportion of total rainfall occurring during each season was: winter, 23.9 percent; spring, 29.7 percent; summer, 24.5 percent; autumn, 21.9 percent.

AGRICULTURAL PRODUCTION

Altho Johnson county is distinctly agricultural, for it has no other industries of importance, only 22 percent of the total acreage was devoted to the growing of grain crops and hay in 1919, as reported by the Census of 1920. This same Census reports that there were 1,742 farms in the county, having an average acreage of 110.8 acres each. This is a slight decrease in the number of farms during the previous decade. Observation indicates that there has been a more rapid decrease in the number of farms since 1919, and that at the present time the number probably does not greatly exceed 1,000.

The principal field crops are corn, wheat, oats, pasture, and hay. Within very recent years, cotton has received considerable attention in this county. The climate of this region is not particularly well suited to cotton production because of danger of frost injury before the crop is mature. The bottom lands, when well drained, are adapted to the growth of this crop, and the comparatively level land adjacent to the bottoms may also be used to good advantage for cotton. Tobacco is grown to some extent and appears to have a more promising future in the county than does cotton. There were about 250 acres grown in 1923 and a consistent increase in acreage is to be expected if prices do not fall below the level of profitable production.

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[1] R. S. Smith, in charge of soil survey mapping; E. A. Norton, first assistant in soil survey mapping; E. E. DeTurk, in charge of soil analysis; F. C. Bauer, in charge of experiment fields; L. H. Smith, in charge of publications.

The Census reports the following as the acreage and yield of some of the more important crops for the year 1919:

Crops	*Acreage*	*Production*	*Yield per acre*
Corn	28,746	545,155 bu.	18.9 bu.
Oats	2,219	33,641 bu.	15.1 bu.
Wheat	7,097	76,856 bu.	10.8 bu.
Timothy	8,680	10,015 tons	1.1 tons
Timothy and clover mixed	5,354	6,202 tons	1.1 tons
Clover (alone)	830	1,063 tons	1.3 tons
Silage crops	842	3,197 tons	3.8 tons
Corn for forage	1,542	1,801 tons	1.1 tons

The total value of all crops in 1919 was $2,210,447.

The soil and topography are the primary factors which make Johnson county a fruit-growing center. This industry is becoming more important each year. The 1920 Census reports the following production of fruit: apples, 126,134 bushels; peaches, 12,689; pears, 5,220; cherries, 890; grapes, 26,268 pounds; and small fruits, including strawberries, raspberries, blackberries, and dewberries, 68,825 quarts. The production of vegetables is receiving increased attention and should become an important industry in the county.

The livestock interests, particularly those of the dairy, are of considerable importance, as shown by the following data, also taken from the Census of 1920.

Animals and Animal Products	*Number*	*Value*
Horses	3,976	$380,613
Mules	2,961	360,553
Beef cattle	4,234	219,798
Dairy cattle	7,634	445,839
Sheep	1,064	15,650
Swine	13,216	169,937
Poultry	96,984	91,672
Eggs and chickens	.....	224,981
Dairy products	.....	222,237
Wool	3,066 lbs.	1,500

The report gives the total value of livestock as more than 1½ million dollars.

SOIL FORMATION

GEOLOGICAL HISTORY

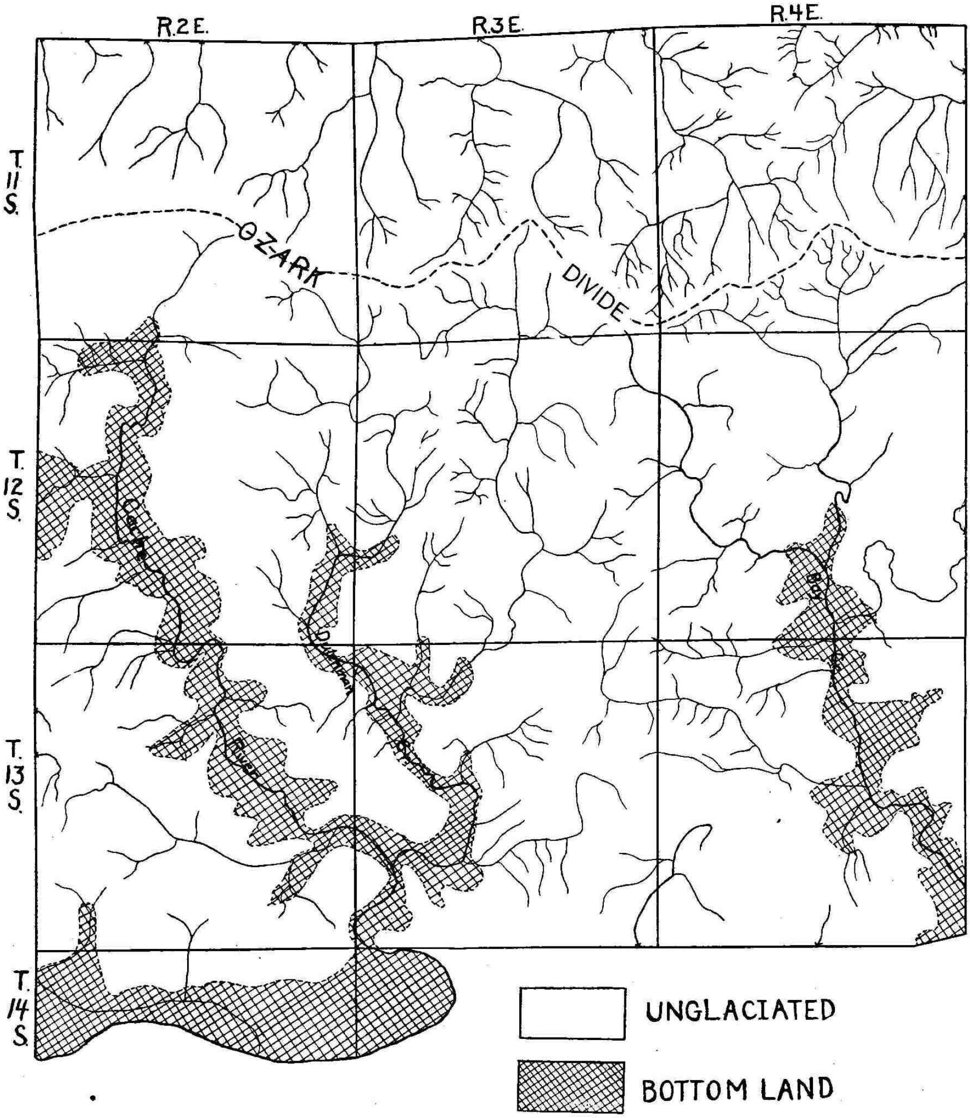
Johnson county lies mostly within a belt of high, rough land that is commonly referred to as a spur of the Ozarks which traverses the near-southern extremity of the state. This rugged area is about 35 miles wide along the Mississippi river in Illinois and covers the whole of Union, the southern part of Jackson, and the northern part of Alexander counties. It extends in a slight northeasterly direction across Johnson county, gradually narrowing until its terminus is reached in the hills of Gallatin county bordering the Ohio river. This uplift rises abruptly from the surrounding country, reaching altitudes of 800 to 1,000 feet above sea level. The region is rough and hilly, not only because of the abruptness with which it rises from the surrounding plains, but also because the agencies of weathering have been at work for a long period of time and an immense amount of erosion has taken place. The hard rocks which are exposed on the surface have been identified as those formed in the Paleozoic era, undoubtedly the oldest geologic formation now exposed in the state.

The natural accumulation of soil material in an unglaciated region, such as Johnson county, is brought about by the disintegration and partial decomposition of the surface rocks in place. This natural breaking down is going on slowly but constantly, owing to the agencies of weathering, such as freezing and thawing, wind, rainfall, and chemical action of various kinds. This accumulation was, for the most part, supplemented by a blanket of water- and wind-transported material, known as loess, deposited during and following the Glacial period. It is one of the most important sources of the soil material.

During the Glacial period, snow and ice accumulated in the region of Labrador and to the west of Hudson bay to such an extent that the mass pushed outward from these centers, chiefly to the south. At least six different ice advances occurred, which were separated by long periods of time. Recent evidence points to the fact that all these glacial advances touched Illinois. None of them, however, came any farther south than the northern boundary of Johnson county. The ice pushing outward gathered up all sorts and sizes of materials, including clay, silt, sand, gravel, boulders, and even immense masses of rock. These materials were ground together and against the surface over which they moved, thus producing an immense amount of fine-grained material known as rock flour. The flood waters from the glaciers carried large quantities of this rock flour and deposited it over the flood plains, or bottom lands. When conditions became such that the volume of flood water decreased, the streams regained their former channels and a portion of the sediment was picked up by the wind and deposited over the upland as dust. This dust, or wind-blown material, is called loess. Johnson county was covered by a deposit of loess which now varies from 1 to 20 feet in depth. It was doubtless at one time more uniform in depth, but erosion has removed large amounts of it, frequently exposing the old residual soil material and in many places the rock itself. In other places, altho erosion has not entirely removed all the loess, it has become so mixed with the residual material that the soil material might be termed residuo-loessial or residuo-aeolial.

EFFECT OF WEATHERING AND OTHER AGENCIES

The soil material was very uniform in color and texture thruout its depth in the earlier periods of its existence. The agencies of weathering, both physical and chemical, acting on the soil material, caused the leaching of certain minerals, the accumulation of others, and the movement of particles into layers, zones, or horizons. This, together with the addition of organic matter from the decay of roots and other plant growth, formed the soil. The accumulation of organic matter has not been great in the soils of Johnson county because of the heavy forest growth which covered this area for many years. Forest vegetation does not favor the accumulation of organic matter because the residues from timber, such as leaves, twigs, dead trees and roots are either destroyed by forest fires or suffer almost complete decay thru exposure to the oxygen of the air and to fungi and other organisms. The weathering forces, acting upon the soil material, bring about the formation of a true subsoil or accumulated zone. This zone, or stratum, is found at a depth of 16 to 20 inches in Johnson county and its character, as regards its degree of plasticity and compaction, is important because of its relation to underdrainage.



MAP SHOWING THE DRAINAGE COURSES OF JOHNSON COUNTY

The alluvial soils found in the bottom lands along the streams are made up largely of material brought down from the uplands of the immediate vicinity. This, of course, is mixed to a greater or less extent with organic matter. In the broader bottom lands the wet condition of the soil has developed a grayish color that is characteristic of the bottom-land soils of this region. In areas where backwater stood, the finest sediment was deposited and this constitutes the clay which is now found in the swampy, poorly-drained lowlands.

PHYSIOGRAPHY AND DRAINAGE

The topography of Johnson county is generally rough and hilly. There is but little level, or nearly level, land except in the bottom land. About 67 per-

cent of the county has been cut up into hills and narrow valleys, which, on account of their excessive slope and large run-off, have enabled the small streams to cause an immense amount of erosion. The lowest part of the county is about 340 feet above sea level, which gives a relief of approximately 450 feet in the county. Numerous perpendicular rock cliffs occur in a belt about four miles wide south of the crest of the Ozark ridge, that extends in an easterly-westerly direction across the northern part of the county.

The following figures give the altitude of certain places in the county: Belknap, 344 feet; Bloomfield, 400; Buncombe, 504; Cypress, 372; Goreville, 715; Grantsburg, 357; New Burnside, 700; Ozark, 668; Parker, 500; Ridenhower, 359; Tunnel Hill, 640; Vienna, 369; West Vienna, 500.

Johnson county lies in four distinct drainage basins, namely, those of Big Bay creek and Cache, Big Muddy, and Saline rivers. Big Bay creek drains about two townships in the southeastern corner of the county. Cache river drains all the remaining territory south of the crest of the Ozark ridge. Both these streams pass thru extensive bottom lands and swamps, and because of the large amount of surface drainage they overflow frequently. The northern and northeastern parts of the county drain into Saline river. All three of the above streams are tributaries of the Ohio river. A small portion of the northwest corner drains north into Big Muddy river, thence to the Mississippi.

With the exception of the broad swamps and bottom lands, the county is well drained. The difficulty is not in getting the water off, but rather in keeping the soil from eroding off with the drainage water. Several drainage projects have been completed in the broad stream valleys, which have reclaimed a large amount of valuable land in the swampy lowlands. Numerous meanders have been developed in the large streams which have nearly reached the base level of erosion. Cache river actually flows about 28 miles in covering a distance of six miles. This makes it difficult to keep the dredge ditches free from brush, logs, and other debris which destroy their efficiency and soon ruin them.

SOIL GROUPS

The soils of Johnson county are divided into the following groups:

Upland Timber Soils, including all the upland areas which are now or were formerly timbered, except those areas on which the loess has been almost or entirely removed.

Residual Soils, including rock outcrop areas, and soils formed in place thru weathering of rocks.

Swamp and Bottom-Land Soils, including the overflow lands or flood plains along streams, the swamps, and the poorly drained lowlands.

Table 1 gives a list of the soil types found in Johnson county, the area of each type in square miles and in acres, and its percentage of the total area of the county.

For explanation concerning the classification of soils and the interpretation of the map and tables, the reader is referred to the first part of the Appendix to this report, beginning on page 19.

TABLE 1.—SOIL TYPES OF JOHNSON COUNTY

Soil type No.	Name of type	Area in square miles	Area in acres	Percent of total area
	Upland Timber Soils (100)			
134	Yellow-Gray Silt Loam	44.18	28,275	13.15
135	Yellow Silt Loam	206.97	132,461	61.60
		251.15	160,736	74.75
	Residual Soils (000)			
098	Stony Loam	12.98	8,307	3.86
099	Rock Outcrop	7.12	4,557	2.12
		20.10	12,864	5.98
	Swamp and Bottom-Land Soils (1300)			
1331	Deep Gray Silt Loam	43.50	27,840	12.94
1361.1	Mixed Fine Sandy Loam	16.59	10,618	4.94
1315	Drab Clay	4.66	2,982	1.39
		64.75	41,440	19.27
	Total	336.00	215,040	100.00

INVOICE OF THE ELEMENTS OF PLANT FOOD IN JOHNSON COUNTY SOILS

In order to obtain a knowledge of its chemical composition, each soil type is sampled in the manner described below and subjected to chemical analysis for its important plant-food elements. For this purpose samples are taken usually in sets of three to represent different strata in the top 40 inches of soil; namely an upper stratum (0 to 6⅔ inches), a middle stratum (6⅔ to 20 inches), and a lower stratum (20 to 40 inches). These sampling strata correspond approximately, in the common kinds of soil, to 2,000,000 pounds per acre of dry soil in the upper stratum, to two times this quantity in the middle stratum, and to three times in the lower stratum.

This, of course, is a purely arbitrary division of the soil section, very useful in arriving at a knowledge of the quantity and distribution of the elements of plant food in the soil, but it should be borne in mind that these strata seldom coincide with the natural strata as they actually exist in the soil and which are referred to in describing the soil types as surface, subsurface, and subsoil. By this system of sampling we have represented separately three zones for plant feeding. The upper, or surface layer, includes at least as much soil as is ordinarily turned with the plow, and this is the part with which the farm manure, limestone, and other fertilizing materials are incorporated.

The chemical analysis of a soil, obtained by the methods here employed, gives the invoice of the total stock of the several plant-food materials actually present in the soil strata sampled. It should be understood, however, that the rate of liberation from their insoluble forms is governed by many factors and is therefore not necessarily proportional to the total amounts present.

For convenience in making application of the chemical analyses, the results as presented here have been translated from the percentage basis and are given in the accompanying tables in terms of pounds per acre. In this, the assump-

tion is made that, for ordinary types, a stratum of dry soil of the area of an acre and 6⅔ inches thick weighs 2,000,000 pounds. It is understood that this value is only an approximation, but it is believed that it will suffice for the purpose intended. It is a simple matter to convert these figures back to the percentage basis if one desires to consider the information in that form.

Because of the extreme variation frequently found within a given soil type with respect to the presence of limestone and acidity in different strata, no attempt is made to include in the tabulated results figures purporting to represent their averages in the respective types. In examining each soil type in the field, however, qualitative tests are made which furnish general information regarding the soil reaction; and in the discussion of the individual soil types recommendations based upon these tests are given concerning the lime requirement of the respective types. Such recommendations cannot be made specific in all cases because local variations exist, and because the lime requirement may change from time to time, especially under cropping and soil treatment. Therefore, it is often desirable to determine the lime requirement for a given field, and in this connection the reader is referred to page 26 of the Appendix.

THE UPPER SAMPLING STRATUM

In Table 2 are reported the amounts of organic carbon (which serves as a measure of the total organic matter), and the total quantities of nitrogen, phosphorus, sulfur, potassium, magnesium, and calcium in 2 million pounds of the surface soil of each type in Johnson county.

In connection with this table, attention is called to the variation among the soil types with respect to their content of the different plant-food elements. It will be seen from the analyses that variations in the organic carbon content of the different soils are accompanied by a similar variation in the nitrogen content. The organic carbon content is usually from 10 to 12 times that of the total nitrogen. This close relationship is explained by the well-established facts that all soil organic matter contains nitrogen and also that most of the soil nitrogen (usually 98 percent or more) is present in a state of organic combination. This close relationship is also maintained in the middle and lower sampling strata. The organic matter and the accompanying nitrogen show considerable variation in the different soil types, tho in no case are the amounts high. The largest amount of organic carbon, 55,640 pounds an acre in the Drab Clay, Bottom, is about equal to that found in the Brown Silt Loam of the corn belt. The corresponding nitrogen content is 4,900 pounds an acre. The smallest amounts of these two elements are found in Stony Loam, where there are 17,980 and 1,140 pounds respectively. Because of the widespread deficiency of both nitrogen and organic matter in these soils, it is particularly important to grow legume crops frequently as green manure and plow them down, in addition to conserving and using all the animal manure which can be produced.

Other elements are not so closely associated with each other as organic matter and nitrogen. However, there is some degree of correlation between sulfur, another element used by growing plants, and organic carbon. This is because a considerable, tho varying, proportion of the sulfur in the soil exists in the organic form, that is, as a constituent of the organic matter. The sulfur

content of Johnson county soils is rather low; it ranges, in the surface soil, from 220 pounds to 860 pounds an acre. This is only partly accounted for by the low organic matter. Another factor is the atmospheric supply; sulfur escapes into the air in the gaseous products from the burning of all kinds of fuel, particularly coal. The gaseous oxid of sulfur is soluble in water and consequently it is dissolved out of the air by rain and brought to the earth. In regions of large coal consumption, the amount of sulfur thus added to the soil is relatively large. At Urbana, as a seven-year average, there was added to the soil by the rainfall, 3.5 pounds of sulfur an acre a month. Similar observations at the Unionville field in Massac county, during the season of 1922, showed a precipitation of less than one pound of sulfur in a month. These facts should not be taken as evidence that sulfur is a limiting factor in crop production, but it would seem that it is more likely to become one in Johnson county than in regions of more abundant supply. A number of fertilizing materials, such as sulfate of ammonia (a nitrogen fertilizer frequently used for fruit trees) acid phosphate, and potassium sulfate, contain sulfur. The use of any of these materials aids in the maintenance of a sulfur supply for the use of growing crops. (See Appendix, page 31.)

All the soils of the county are well supplied with potassium, the amounts present in the surface soil ranging from 21,340 pounds to 34,860 pounds an acre. As indicated by the experiments at Unionville, in Massac county, the soil potassium of the Yellow-Gray Silt Loam becomes available in the soil rapidly enough to meet the needs of some crops but not of corn and cotton, at the present level of production. These crops have responded to potassium fertilization. In the case of seed cotton, the average annual gain from potassium amounted to 193 pounds, or 73 percent, as compared with a plot otherwise similar but receiving no potassium. The increase in the yield of corn has averaged 5 bushels an acre a year for the potassium treatment, or 13.4 percent.

The phosphorus content of these soils is above the average for the corresponding types. The minimum amount found, namely, 890 pounds an acre in Yellow Silt Loam, is exceeded in the same soil type in only three counties of the twenty-eight for which reports have been published. The largest amount of phosphorus, 1,480 pounds an acre, is found in Drab Clay, Bottom.

As contrasted to the phosphorus supply in these soils, the calcium and magnesium contents are very low. Yellow Silt Loam, with but one exception contains, in the surface soil, the smallest quantity of both calcium and magnesium shown in any of the previous soil reports. These amounts are 4,630 and 3,370 pounds an acre, respectively. The other soil types in the county, except Drab Clay, are all comparatively low in calcium and magnesium. Because of the small amount of magnesium required by growing plants it is doubtful, even in soils as low as these, if this element ever becomes a limiting factor in crop growth. This is not true, however, of calcium, which is taken up from the soil in much larger amounts by crop plants. While low calcium content is not always associated with soil acidity, it very frequently is, as in this county, in which practically all the soils are more or less acid. This is more particularly noticeable in the lower strata, which are much more strongly acid than the surface soil and also contain proportionately less calcium. However, since limestone contains 40 percent of cal-

cium, which is easily available to crop plants, the calcium problem is automatically taken care of by additions of lime to correct acidity.

THE MIDDLE AND LOWER SAMPLING STRATA

In Tables 3 and 4 are recorded the amounts of the plant-food elements in the middle and lower sampling strata. In comparing these strata with the upper stratum, or with each other, it is necessary to bear in mind that the data as given for the middle and lower sampling strata are on the basis of 4 million and 6 million pounds of soil, and should therefore be divided by two and three, respectively, before being compared with each other or with the data for the upper stratum, which is on a basis of 2 million pounds.

With this in mind, it will be noted in comparing the three strata with each other, that all the soil types diminish rather rapidly in organic matter and nitrogen with increasing depth. Ordinarily, the percentages of the other elements remain about the same, or increase slightly in the lower strata. But we do not find this to be the case in Johnson county. Only the potassium remains approximately constant in the three strata. The percentages of sulfur and calcium are markedly lower in both the lower strata, while those of phosphorus and magnesium show considerable increase. This is especially true of magnesium, which is more than twice as concentrated in the middle and lower strata as in the surface.

These relationships may be explained by the great amount of leaching to which the soil has been subjected on account of its age and the comparatively heavy rainfall. Sulfur and calcium are fairly soluble and consequently have been leached away more rapidly than the soil mass as a whole. Sulfur also, by virtue of its relation to organic matter, may be expected to diminish with increasing depth. Phosphorus and magnesium, on the other hand, are much less soluble, and since both are readily fixed by the soil in insoluble forms, they have therefore tended to accumulate in the lower levels. It is a well-established fact that magnesium will replace calcium in minerals such as are found in the soil. It would therefore appear that magnesium, which is dissolved near the surface, as it percolates down thru the soil displaces calcium from its mineral combinations in the lower layers, so that the latter is leached away while the magnesium itself becomes fixed. Potassium, by virtue of its very low solubility, has not dissolved and passed downward to an extent that would appreciably affect the relative amounts in the different layers. These statements do not apply to the bottom-land soils, where the effects of overflow largely offset the effects of leaching.

It is frequently of interest to know the total supply of a plant-food element accessible to the growing crops. While it is impossible to obtain this information exactly, especially for the deeper-rooted crops, it seems probable that practically all the feeding range of the roots of most of our common field crops is included in the upper 40 inches of soil. By adding together for a given soil type, the corresponding figures in Tables 2, 3, and 4, the total amounts of the respective plant-food elements to a depth of 40 inches may be ascertained.

No very wide range of variation with respect to composition is found to occur in the sub-layers or in the top layers of the various soil types, except as between upland and bottom soils. The tables reveal, however, that there is a

considerable variation with respect to the relative abundance of the various elements within a given soil type as measured by crop requirements. We may compare in this way two extreme soil types in the county, namely, Drab Clay, Bottom, and Yellow-Gray Silt Loam, Upland. The respective amounts of nitrogen in the two soils to a depth of 40 inches are 16,360 and 5,930 pounds an acre, which is equivalent to the nitrogen contained in the same number of bushels of corn, since a bushel of corn contains approximately a pound of nitrogen. The Drab Clay thus contains nearly three times as much of this element as the Yellow-Gray Silt Loam. With regard to the phosphorus and potassium contents of the two soil types, there is no significant difference; Drab Clay contains 6,700 pounds of phosphorus, which is equivalent to the amount in 39,500 bushels of corn and Yellow-Gray Silt Loam 6,670 pounds, which is equivalent to 39,300

TABLE 2.—PLANT-FOOD ELEMENTS IN THE SOILS OF JOHNSON COUNTY ILLINOIS
UPPER SAMPLING STRATUM: ABOUT 0 TO 6⅔ INCHES

Average pounds per acre in 2 million pounds of soil

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total sulfur	Total potassium	Total magnesium	Total calcium
	Upland-Timber Soils (100)							
134	Yellow-Gray Silt Loam..	19,470	1,960	970	390	31,420	4,620	4,010
135	Yellow Silt Loam.......	20,240	1,950	890	390	30,560	4,630	3,370
	Residual Soils (000)							
098	Stony Loam............	17,980	1,140	940	220	21,340	3,200	3,040
	Swamp and Bottom-Land Soils (1300)							
1331	Deep Gray Silt Loam....	28,490	2,970	1,400	490	33,700	7,220	6,220
1361.1	Mixed Fine Sandy Loam[1]							
1315	Drab Clay.............	55,640	4,900	1,480	860	34,860	14,320	14,220

LIMESTONE AND SOIL ACIDITY.—In connection with these tabulated data, it should be explained that the figures for limestone content and soil acidity are omitted not because of any lack of importance of these factors, but rather because of the peculiar difficulty of presenting in the form of numerical averages reliable information concerning the limestone requirement for a given soil type. A general statement, however, will be found concerning the lime requirement of the respective soil types in connection with the discussions which follow.

[1]Chemical analyses are not included for Mixed Fine Sandy Loam on account of the heterogeneous character of this type.

bushels of corn. The total amounts of potassium in the two soil types, are 208,260 and 202,310 pounds, respectively, which are equivalent approximately to the amounts in 1,096,000 and 1,065,000 bushels of corn. There is wide variation in the calcium content, the amounts being 96,140 pounds in Drab Clay and 21,420 in Yellow-Gray Silt Loam. Since a ton of red clover hay contains approximately 29 pounds of calcium, these two soils contain as much calcium as would be removed in 3,310 and 740 tons of red clover hay, respectively.

The above statements are not intended to imply that it is possible to predict how long it might be before a certain soil would become exhausted under a given system of cropping. Neither do the figures necessarily indicate the immediate procedure to be followed in the improvement of a soil, for other factors enter into consideration, aside from merely the amount of plant-food elements

TABLE 3.—PLANT-FOOD ELEMENTS IN THE SOILS OF JOHNSON COUNTY, ILLINOIS
MIDDLE SAMPLING STRATUM: ABOUT 6⅔ TO 20 INCHES

Average pounds per acre in 4 million pounds of soil

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total sulfur	Total potassium	Total magnesium	Total calcium
				Upland Timber Soils (100)				
134	Yellow-Gray Silt Loam..	13,780	2,000	2,220	660	67,580	14,900	6,550
135	Yellow Silt Loam.......	16,740	2,140	1,860	440	65,420	12,980	4,690
				Residual (000)				
098	Stony Loam...........	16,680	1,640	2,640	480	44,320	10,480	4,600
				Swamp and Bottom-Land Soils (1300)				
1331	Deep Gray Silt Loam...	23,530	2,780	2,090	560	64,770	13,630	10,050
1361.1	Mixed Fine Sandy Loam[1]							
1315	Drab Clay.............	70,600	6,000	2,640	1,240	70,440	37,120	31,400

LIMESTONE AND SOIL ACIDITY.—See note in Table 2.

[1]Chemical analyses are not included for Mixed Fine Sandy Loam on account of the heterogeneous character of this type.

present in the soil. Much depends upon the nature of the crops to be grown, as to their utilization of plant-food materials, and much depends upon the condition of the plant-food substances themselves as to their availability. Finally in planning the detailed procedure for the improvement of a soil there enter for consideration all the economic factors involved in any fertilizer treatment. Such figures do, however, furnish an inventory of the total stocks of the plant-food elements that can possibly be drawn upon, and in this way contribute fundamental information for the intelligent planning, in a broad way, of systems of soil management for conserving and improving the fertility of the land.

TABLE 4.—PLANT-FOOD ELEMENTS IN THE SOILS OF JOHNSON COUNTY, ILLINOIS
LOWER SAMPLING STRATUM: ABOUT 20 TO 40 INCHES

Average pounds per acre in 6 million pounds of soil

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total sulfur	Total potassium	Total magnesium	Total calcium
				Upland Timber Soils (100)				
134	Yellow-Gray Silt loam..	10,070	1,970	3,480	530	103,310	32,300	10,860
135	Yellow Silt Loam.......	11,020	1,790	2,940	370	104,570	28,940	9,800
				Residual Soils (000)				
098	Stony Loam[1]							
				Swamp and Bottom-Land Soils (1300)				
1331	Deep Gray Silt Loam...	21,260	2,950	2,680	850	91,720	21,110	16,270
1361.1	Mixed Fine Sandy Loam[2]							
1315	Drab Clay.............	77,880	5,460	2,580	1,260	102,960	58,920	50,520

LIMESTONE AND SOIL ACIDITY.—See note in Table 2.

[1]No sample could be collected on account of the stony nature of this stratum.
[2]Chemical analyses are not included for Mixed Fine Sandy Loam because of the heterogeneous character of this type.

DESCRIPTION OF SOIL TYPES

UPLAND TIMBER SOILS

The upland timber soils include all the upland areas that are now or were formerly timbered, with the exception of those areas which are classified as Stony Loam or Rock Outcrop, from which the loess has been partially or entirely removed by erosion. The timber soils are characterized by a brownish yellow, yellow, or yellowish gray color. The low percentage of organic matter which characterizes these soils is the result of long-continued growth of forests. Prairie grasses, which furnish large amounts of organic matter, do not grow to any extent in the shaded timber areas. The organic material in forests, such as leaves and twigs, does not accumulate in the soil, but is either burned or suffers almost complete decay. Moreover, the organic matter that may have accumulated in the soil before the timber began growing is slowly removed by decomposition and leaching. The result is that the contents of organic matter and nitrogen in the timber soils are low.

Yellow-Gray Silt Loam (134)

The growth of forest trees has been an important factor in the development of Yellow-Gray Silt Loam. Timber ordinarily starts along streams and on the better drained areas and gradually spreads. No doubt some of the area now classified as Yellow Silt Loam was formerly Yellow-Gray Silt Loam, but erosion, which is active in this region, has removed much of the soil material, making many of the formerly undulating or rolling areas rough and broken. Yellow-Gray Silt Loam occupies a total area of 44.18 square miles, or more than 13 percent of the area of the county. It occurs in irregular tracts and is found either as flat to undulating bench land along streams, or as rolling areas on the comparatively level tops of ridges. Many isolated areas occur in the county, but the major portion of the type is found in the southern tier of townships.

There are two distinct phases of Yellow-Gray Silt Loam in the county, corresponding to the differences in topography and location as noted above. The flat to gently undulating phase is found principally along Cache river and its tributaries in the vicinity, and south of Vienna. This phase of the type occurs as a bench-like formation. The rolling phase of the type occurs as irregular areas on the comparatively level tops of ridges scattered thruout the county. As indicated, its topography is rolling, often breaking off suddenly into an exceptionally steep phase of Yellow Silt Loam.

The surface soil of the undulating phase of Yellow-Gray Silt Loam, 0 to 5 inches, is a brownish yellow, friable, coarse silt loam, often containing an appreciable amount of medium and fine sand. The subsurface soil, 5 to 16 inches, is a friable, mottled, grayish yellow silt loam, and also contains a perceptible amount of fine sand. The subsoil is divided into two distinct layers. The upper stratum, 16 to 36 inches, is a compact, mottled yellow silt loam, often rather plastic when wet; the lower stratum is friable and is usually brighter yellow in color than the upper stratum.

The rolling phase of the type differs from the undulating phase in that the surface soil rarely exceeds 2 inches in depth, a high percentage of fine sand is uniformly distributed thruout the soil section, and the transition from one

stratum to the next is gradual. The upper subsoil, however, is compact and well developed. The depth to bed rock varies from about 5 to 20 feet.

Management.—This type is very low in organic matter and nitrogen and is somewhat acid, tho apparently not strongly so. The degree of acidity generally increases with increasing depth to about 6 or 7 feet. Red clover will not grow on this land unless it is either limed or heavily manured. Sweet clover will not grow without lime. Alfalfa can be grown with fair success following sweet clover; however, it is not a sure crop because of the excessive heaving which often occurs during the winter and early spring and the tendency to die out during the hot dry weather in July and August. Cowpeas do well without lime, and mixed clover and timothy hay yields well following the application of 2 to 4 tons of limestone per acre. It is advisable to secure the assistance of the county farm adviser or of the Experiment Station in determining the amount of limestone to apply since the need varies from place to place. The fineness of the stone is also an important factor in determining the rate of application.

Cotton may be grown on this type, particularly on the bench-like portion of the type, but it is necessary to handle the soil and crop in such a way that a vigorous early growth is secured, in order that the crop may mature before frost. The reader is referred to Illinois Circular 279 for special directions regarding the fertilization and management of the cotton crop.

Unless the land is well treated, corn is not a good crop for this soil because the seasonal conditions are very often such that the crop suffers from drouth. The average yield of wheat in the county is only about 11 bushels an acre, and this yield is not far from the average for this soil type; moreover, no material increase in yield can be expected unless provision is made for improving the soil.

In the management of this type, a rotation should be adopted in which clover is grown at frequent intervals. All manure should be conserved and applied for corn or on the timothy sod. Information is not available upon which to base definite recommendations regarding the use of other fertilizing materials. Results secured on the Elizabethtown experiment field in Hardin county, which is located on soil that is similar to this type, indicate that the growth of sweet clover is very much increased by rock phosphate and that the following corn crop shows a similar response, probably largely because of the increased clover growth. Acid phosphate has given larger increases in the yield of wheat than has rock phosphate. It is suggested that a trial be made of either, or both, of these phosphates, after the need for lime, nitrogen, and fresh organic matter has been met. Rock phosphate should be applied at the rate of at least 1,000 pounds per acre and plowed down for wheat with some kind of organic matter. Acid phosphate should be applied at the rate of about 300 pounds per acre with a drill, or broadcasted after plowing for wheat and worked into the soil as the seed bed is being prepared. The use of potash salts may prove profitable when applied for corn or cotton, but sufficient information is not now available to justify any definite recommendations.

Yellow Silt Loam (135)

Yellow Silt Loam is by far the most common soil type and occurs thruout the entire county. It covers an area of 206.97 square miles, or nearly 62 percent

FIG. 1.—A FIELD IN WHICH EROSION IS STARTING ITS DESTRUCTIVE WORK
This view was taken on a farm adjoining the old Vienna experiment field.

of the entire area. This type varies in topography from rolling to extremely rough and hilly, and includes much land which should not be cultivated. On the steeper slopes, much of the loessial soil material has been removed by erosion, so that the soil is constituted either of the residual material derived from the weathered rock or of a mixture of this with loessial material. The soil of these areas from which the loessial material has been removed is a red or reddish yellow clay mixed with some angular cherty or flinty pebbles. Slopes facing the north are frequently very abrupt, while those to the south are more gradual. Much of this land is so badly gullied or washed that it has been abandoned agriculturally. Land of this character should never have been cleared of its protecting forests. It would, no doubt, be more economical to return this rough, badly eroded land to timber and thus in time place it on a paying basis, rather than to allow it to waste away. The less-broken portions of this type can

FIG. 2.—THIS IS THE SAME FIELD AS SHOWN IN FIG. 1, BUT TEN YEARS LATER

be utilized for pasturing and orcharding. Because of its yellow color, this type of soil is commonly termed clay, and the type as a whole spoken of as clay hills. In reality, it contains very little clay, much less than other soil types in the county.

Erosion is so active on the area occupied by Yellow Silt Loam that a true surface soil is seldom found. Where present, it is but 2 or 3 inches deep, and is a brownish yellow, friable, silt loam. It often contains much fine sand. The subsurface also has been in part or entirely removed from many areas, and it may therefore be present in its entirety or it may be partly or wholly absent. On the areas which have not been subjected to more recent erosion, it occurs as a stratum about 18 inches thick, and consists of a light grayish yellow, friable, silt loam. It always contains an appreciable amount of fine sand. The subsoil when present consists of two strata: the upper stratum, to a depth of 50 inches, is a compact, strongly mottled, yellow silt loam, or less frequently, clay loam; the lower, below 50 inches, is a friable, mottled yellow silt loam. The thickness of this lower subsoil stratum is determined by the amount of erosion that has taken place. It varies from a few inches to about 14 feet.

Management.—The management of this type presents peculiar difficulties. Erosion is severe and constant watchfulness is necessary to prevent serious damage being done to tilled fields by gullying and sheet washing. The reader is referred to Illinois Circular 290 for a discussion of terracing as one means of controlling erosion, and to Illinois Bulletin 207 for a thoro discussion of the general subject of erosion. The removal of most of the timber, and the subsequent rapid disappearance of the small amount of organic matter which had accumulated on the surface of the soil, left this land with nothing to protect it from washing. Much of the area is fit only for timber and pasturing, certain

FIG. 3.—BLACK LOCUSTS GROWING ON BADLY ERODED LAND
Much of this rough land might well be devoted to the production of timber rather than the growing of cultivated crops.

portions may be used for orcharding, and the less steep slopes may be farmed successfully if precautions are taken to prevent erosion. The soil is invariably acid, and is very low in nitrogen and organic matter. Where limestone can be applied, sweet clover is an excellent crop to be grown for pasture, or it may be used as a combination hay and pasture crop. The soil is usually saturated with water in the spring and stock should be kept off until it becomes firm enough not to be injured by tramping. Cowpeas grow well without any lime and make excellent hay for dairy cattle and other stock.

There are many areas in the county which are so isolated on account of bad roads as to make it impossible to apply limestone unless it can be secured from local crushers. In case a limestone outcrop is available but no crusher can be secured, the practicability of converting the stone to a usable condition by home burning is worth investigating.

No practicable way is now known for improving this worn hill land unless some lime material can be applied. There may be possibilities of doing this by the introduction of leguminous plants not now common to the region, which will grow in acid soils. These possibilities have, however, not been investigated, and until they are, no adequate suggestions can be made for building up this soil unless lime in some form can be applied.

After the nitrogen and organic deficiencies of this soil have been met, in part at least, then the advisability of using phosphates and other fertilizers profitably should be determined by trials on limited areas.

RESIDUAL SOILS

These soils are formed in part by the weathering of the underlying rocks that have been exposed by erosion, and this weathered material has been more or less mixed with the wind-blown loessial material. This group of soils occurs chiefly on the south approach to the crest of the Ozark ridge. Their topography is extremely rough.

Stony Loam (098)

Stony Loam occurs principally in Simpson township, but small areas occur in almost every township. The total area is about 13 square miles. The stones occurring are principally sandstone and they vary in size from a few inches to several feet in diameter. These stones are mixed with more or less fine soil material, fine sand almost always forming one-third or more of the total. Occasional rock ledges are found in these areas that are too small to be shown separately. This type is adapted only to forestry and pasture.

Rock Outcrop (099)

Rock Outcrop occurs most abundantly in an east-west belt across the county just south of the crest of the Ozark ridge. The total area of Rock Outcrop is 7.12 square miles. The width of the individual areas is often exaggerated on the soil map in order to show the perpendicular cliffs.

The outcropping rock, especially that found in the northern part of the county, is principally sandstone, known as Pennsylvanian rocks. Outcrops of limestone, Mississippian rocks, occur in the vicinity of Vienna and others occur

near Cypress. These limestone outcrops may well be used as sources of limestone for agricultural purposes. At the present time limestone is being crushed for that purpose at White Hill. This limestone contains carbonates equivalent to about 88 or 90 percent calcium carbonate. Outcrops of shale also occur in connection with some of the sandstone on the south side of the Ozark ridge.

SWAMP AND BOTTOM-LAND SOILS

This group of soils includes the bottom land along streams, the swamps, and the poorly drained lowlands. Much of the soil, therefore, is of alluvial formation and the land is largely subject to overflow. The overflow is difficult to control because of the heavy rainfall and quick run-off from the surrounding hills. The run-off in this region is estimated to be 50 percent of the total rainfall, so the streams must carry large amounts of water. Dredging, resulting in the straightening, widening, and deepening of the stream channels, has been carried out in some places, thereby materially decreasing the amount of damage by overflow. The completion of Post Creek Cut-Off, which shunts the water from Cache river directly to the Ohio, gives a much better outlet than any heretofore had. This has made the smaller dredge ditches in the county more efficient.

For many years the lowlands along Cache river in Cache township, (Township 14 South, Range 2 East) have been shallow ponds or lakes, and still are during wet seasons. Backwater was forced into the ponds by the streams, and from this backwater, the finer soil particles were deposited. This deposit constitutes the dark heavy soil of the present swampy areas. The bottom-land soils in Johnson county constitute nearly 20 percent of the total area of the county.

Deep Gray Silt Loam (1331)

Deep Gray Silt Loam is the most extensive bottom-land type in the county, occupying an area of 43.5 square miles, or 12.94 percent of the total area of the county. It occurs principally along the courses of the three largest streams, Cache river in the west, Dutchman creek in the center, and Bay creek in the east. Its distribution along those streams is irregular, varying from a few rods to nearly two miles in width.

The surface soil of Deep Gray Silt Loam is a yellowish gray, friable, mealy, silt loam, containing considerable fine sand. It is rather variable, however, ranging from a sandy to a clayey phase, depending on its position with reference to the stream channel. Near the channel, where the overflow is frequent, the soil is more sandy. Away from the channel, where there is practically no current, the soil is heavier, containing more clay. The subsurface soil is a continuation of the surface except that the yellow color gradually fades away with increasing depth, and the content of silt is more uniform. The subsoil below 18 inches is a slightly compact, gray, silty clay loam, except where the deposit is recent. Along stream channels the subsoil is more of a silty or fine sandy nature and not so compact.

Management.—Deep Gray Silt Loam is the best soil in Johnson county. It is not strongly acid and those portions which are subject to overflow will not become acid. Poor drainage characterizes the type. Means should be provided for the rapid removal of flood and other water by the construction of open

ditches and by the laying of tile drains. The organic-matter and nitrogen contents of this soil are low and are difficult to maintain on the overflow areas. Every effort should be made to increase these soil constituents by the use of legumes, manure, and crop residues. No definite fertilizer recommendation can be made at the present time, but it is suggested that, if wheat is grown, rock or acid phosphate be tried as suggested for Yellow-Gray Silt Loam (page 13). If cotton is grown, the suggestions in Illinois Circular 279 should be followed.

Mixed Fine Sandy Loam (1361.1)

Mixed Fine Sandy Loam occurs along the smaller streams and represents areas usually not over a quarter of a mile wide. It is formed of material brought down from the upland of the immediate vicinity. Whenever a big rain overflows these bottoms, the coarser material is deposited in them, while the finer is carried out into the larger bottoms of Deep Gray Silt Loam. Because of frequent overflow with the deposition of new material, this type is variable. Mixed Fine Sandy Loam covers an area of 16.59 square miles.

The surface soil to a depth of 6 or 7 inches is usually a grayish yellow, loose, fine sandy loam. The subsurface soil to a depth of about 18 inches is a loose, yellow fine sandy loam. The subsoil is a yellow, fine sandy loam mixed with some coarser material such as gravel and small rock. The average depth of the soil to the rock base is about 5 feet, but it ranges from a few inches to 10 or 12 feet.

Management.—This type is somewhat acid even tho it is practically all overflow land. The rapid removal of flood water is an important consideration in its management. It is an easily worked soil because of its high sand content, but its sandy, open character, together with its frequent flooding, makes the maintenance of nitrogen and organic matter difficult and particular attention must be given to this phase of its management.

Drab Clay (1315)

Drab Clay occurs in the swampy, poorly drained lowlands along Cache river in the southwestern part of the county. It has been formed by the deposition of the finest soil material in the backwater caused by stream overflow. It comprizes 4.66 square miles, or 1.39 percent of the area of the county.

The surface soil, 0 to 5 inches, varies from a brownish gray, sandy clay loam to a dark drab, granular, plastic clay. Its character depends on the amount of recent deposit. Near the upland and the creek channels considerable silt and sand are present, while a typical drab clay is found in the center of the areas. The subsurface to about 20 inches is a very plastic, grayish or bluish drab clay. The subsoil is a fairly plastic, yellowish gray clay.

Management.—This type is adapted only to timber production because of its swampy, plastic, and compact nature.

APPENDIX

EXPLANATIONS FOR INTERPRETING THE SOIL SURVEY

CLASSIFICATION OF SOILS

In order intelligently to interpret the soil maps, the reader must understand something of the method of soil classification upon which the survey is based. Without going far into details the following paragraphs are intended to furnish a brief explanation of the general plan of classification used.

The type is the unit of classification and each type has definite characteristics. In establishing types, the following factors are taken into account: the character of the horizons composing the soil as to depth and thickness, physical composition, structure, organic-matter content, color, reaction, and carbonate content; the topography; the native vegetation; and the geological origin of the soil.[1]

Not infrequently areas are encountered in which type characters are not distinctly developed or in which they show considerable variation. When these variations are considered to have sufficient significance, type separations are made whenever the areas involved are sufficiently large. Because of the almost infinite variability occurring in soils, one of the exacting tasks of the soil surveyor is to determine the degree of variation which is allowable for any given type.

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[1] Since some of the terms used in designating the factors which are taken into account in establishing soil types are technical in nature, the following explanations are introduced:

Horizon. A layer or stratum of soil which differs discernibly from those adjacent in color, texture, structure, chemical composition, or a combination of these characteristics, is called an horizon.

Depth and Thickness. The horizons or layers which make up the soil profile vary in depth and thickness. These variations are distinguishing features in the separation of soils into types.

Physical Composition. The physical composition, sometimes referred to as "texture," is a most important feature in characterizing a soil. The texture depends upon the relative proportions of the following physical constituents: clay, silt, fine sand, sand, gravel, stones, and organic material.

Structure. The term "structure" has reference to the aggregation of particles within the soil mass and carries such qualifying terms as open, granular, compact.

Organic-Matter Content. The organic matter of soil is derived largely from plant tissue and it exists in a more or less advanced stage of decomposition. Organic matter forms the predominating constituent in certain soils of swampy formation.

Color. Color is determined to a large extent by the proportion of organic matter, but at the same time it is modified by the mineral constituents, especially by iron compounds.

Reaction. The term "reaction" refers to the chemical state of the soil with respect to acid or alkaline condition. It also involves the idea of degree, as strongly acid or strongly alkaline.

Carbonate Content. The carbonate content has reference to the calcium carbonate (limestone) present, which in some cases may be associated with magnesium or other carbonates. The depth at which carbonates are found may become a very important factor in determining the soil type.

Topography. Topography has reference to the lay of the land, as level, rolling, hilly, etc.

Native Vegetation. The vegetation or plant growth before being disturbed by man, as prairie grasses and forest trees, is a feature frequently recognized in determining soil types.

Geological Origin. Geological origin involves the idea of character of rock materials composing the soil as well as the method of formation of the soil.

Classifying Soil Types.—In the system of classification used, the types fall first into four general groups based upon their geological relationships; namely, upland, terrace, swamp and bottom land, and residual. These groups may be subdivided into prairie soils and timber soils, altho as a matter of fact this subdivision is applied in the main only to the upland group. These terms are all explained in the foregoing part of the report in connection with the description of the particular soil types.

Naming and Numbering Soil Types.—In the Illinois soil survey a system of nomenclature is used which is intended to make the type name convey some idea of the nature of the soil. Thus the name "Yellow-Gray Silt Loam" carries in itself a more or less definite description of the type. It should not be assumed, however, that this system of nomenclature makes it possible to devise type names which are adequately descriptive, because the profile of mature soils is usually made up of four or more horizons and it is impossible to describe each horizon in the type name. The color and texture of the surface soil are usually included in the type name and when material such as sand, gravel, or rock lies at a depth of less than 30 inches, the fact is indicated by the word "on," and when its depth exceeds 30 inches, by the word "over"; for example, Brown Silt Loam On Gravel, and Brown Silt Loam Over Gravel.

As a further step in systematizing the listing of the soils of Illinois, recognition is given to the location of the types with respect to the geological areas in which they occur. According to a geological survey made many years ago, the state has been divided into seventeen areas with respect to geological formation and, for the purposes of the soil survey, each of these areas has been assigned an index number. The names of the areas together with their general location and their corresponding index numbers are given in the following list.

000	*Residual,* soils formed in place thru disintegration of rocks, and also rock outcrop
100	*Unglaciated,* comprizing three areas, the largest being in the south end of the state
200	*Illinoisan moraines,* including the moraines of the Illinoisan glaciations
300	*Lower Illinoisan glaciation,* covering nearly the south third of the state
400	*Middle Illinoisan glaciation,* covering about a dozen counties in the west-central part of the state
500	*Upper Illinoisan glaciation,* covering about fourteen counties northwest of the middle Illinoisan glaciation
600	*Pre-Iowan glaciation,* but now believed to be part of the upper Illinoisan
700	*Iowan glaciation,* lying in the central northern end of the state
800	*Deep loess areas,* including a zone a few miles wide along the Wabash, Illinois, and Mississippi rivers
900	*Early Wisconsin moraines,* including the moraines of the early Wisconsin glaciation
1000	*Late Wisconsin moraines,* including the moraines of the late Wisconsin glaciation
1100	*Early Wisconsin glaciation,* covering the greater part of the northeast quarter of the state
1200	*Late Wisconsin glaciation,* lying in the northeast corner of the state
1300	*Old river-bottom and swamp lands,* found in the older or Illinoisan glaciation
1400	*Late river-bottom and swamp lands,* those of the Wisconsin and Iowan glaciations
1500	*Terraces,* bench or second bottom lands, and gravel outwash plains
1600	*Lacustrine deposits,* formed by Lake Chicago, the enlarged glacial Lake Michigan

For further information regarding these geological areas the reader is referred to the general map published in Bulletins 123 and 193.

Another set of index numbers is assigned to the classes of soils as based upon physical composition. The following list contains the names of these classes with their corresponding index numbers.

Index Number Limits	Class Names
0 to 9	Peats
10 to 12	Peaty loams
13 to 14	Mucks
15 to 19	Clays
20 to 24	Clay loams
25 to 49	Silt loams
50 to 59	Loams
60 to 79	Sandy loams
80 to 89	Sands
90 to 94	Gravelly loams
95 to 97	Gravels
98	Stony loams
99	Rock outcrop

As a convenient means of designating types and their location with respect to the geological areas of the state, each type is given a number made up of a combination of the index numbers explained above. This number indicates the type and the geological area in which it occurs. The geological area is always indicated by the digits of the order of hundreds while the balance of the number designates the type. To illustrate: the number 1126 means Brown Silt Loam in the early Wisconsin glaciation, 434 means Yellow-Gray Silt Loam of the middle Illinoisan glaciation. These numbers are especially useful in designating very small areas on the map and as a check in reading the colors.

A complete list of the soil types occurring in each county, along with their corresponding type numbers and the area covered by each type, will be found in the respective county soil reports in connection with the maps.

SOIL SURVEY METHODS

Mapping of Soil Types.—In conducting the soil survey, the county constitutes the unit of working area. The field work is done by parties of two to four men each. The field season extends from early in April to Thanksgiving. During the winter months the men are engaged in preparing a copy of the soil map to be sent to the lithographer, a copy for the use of the county farm adviser until the printed map is available, and a third copy for use in the office in order to preserve the original official map in good condition.

An accurate base map for field use is necessary for soil mapping. These maps are prepared on a scale of one inch to the mile, the official data of the original or subsequent land survey being used as the basis in their construction. Each surveyor is provided with one of these base maps, which he carries with him in the field; and the soil type boundaries, together with the streams, roads, railroads, canals, town sites, and rock and gravel quarries are placed in their proper location upon the map while the mapper is on the area. With the rapid development of road improvement during the past few years, it is almost inevitable that some recently established roads will not appear on the published soil map. Similarly, changes in other artificial features will occasionally occur in the interim between the preparation of the map and its publication. The detail or minimum size of areas which are shown on the map varies somewhat, but in general a soil type if less than five acres in extent is not shown.

A soil auger is carried by each man with which he can examine the soil to a depth of 40 inches. An extension for making the auger 80 inches long is taken

by each party, so that the deeper subsoil may be studied. Each man carries a compass to aid in keeping directions. Distances along roads are measured by a speedometer or other measuring device, while distances in the field away from the roads are measured by pacing.

Sampling for Analysis—After all the soil types of a county have been located and mapped, samples representative of the different types are collected for chemical analysis. The samples for this purpose are usually taken in three depths; namely, 0 to 6⅔ inches, 6⅔ to 20 inches, and 20 to 40 inches, as explained in connection with the discussion of the analytical data on page 6.

PRINCIPLES OF SOIL FERTILITY

Probably no agricultural fact is more generally known by farmers and landowners than that soils differ in productive power. A fact of equal importance, not so generally recognized, is that they also differ in other characteristics such as response to fertilizer treatment and to management.

The soil is a dynamic, ever-changing, exceedingly complex substance made up of organic and inorganic materials and teeming with life in the form of microorganisms. Because of these characteristics, the soil cannot be considered as a reservoir into which a given quantity of an element or elements of plant food can be poured with the assurance that it will respond with a given increase in crop yield. In a similar manner it cannot be expected to respond with perfect uniformity to a given set of management standards. To be productive a soil must be in such condition physically with respect to structure and moisture as to encourage root development; and in such condition chemically that injurious substances are not present in harmful amounts, that a sufficient supply of the elements of plant food become available or usable during the growing season, and that lime materials are present in sufficient abundance favorable for the growth of the higher plants and of the beneficial microorganisms. Good soil management under humid conditions involves the adoption of those tillage, cropping, and fertilizer treatment methods which will result in profitable and permanent crop production on the soil type concerned.

The following paragraphs are intended to state in a brief way some of the principles of soil management and treatment which are fundamental to profitable and continued productivity.

CROP REQUIREMENTS WITH RESPECT TO PLANT-FOOD MATERIALS

Ten different elements of plant food are essential for the growth and formation of every plant. These elements are: *carbon, oxygen, hydrogen, nitrogen, phosphorus, sulfur, potassium, magnesium, calcium, and iron.* Some seasons in central Illinois are sufficiently favorable to allow the production of at least 50 bushels of wheat per acre, 100 bushels of corn, 100 bushels of oats, and 4 tons of clover hay. When such crops, growing under favorable climatic and cultural conditions and uninjured by disease or insect pests, are not produced the failure is due to unfavorable soil conditions, which may result from poor drainage, poor physical condition, or from an actual deficiency in one or more of the elements of plant food.

TABLE 5.—PLANT-FOOD ELEMENTS IN COMMON FARM CROPS[1]

Produce: Kind	Produce: Amount	Nitrogen	Phosphorus	Sulfur	Potassium	Magnesium	Calcium	Iron
		lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*
Wheat, grain......	1 bu.	1.42	.24	.10	.26	.08	.02	.01
Wheat straw......	1 ton	10.00	1.60	2.80	18.00	1.60	3.80	.60
Corn, grain.......	1 bu.	1.00	.17	.08	.19	.07	.01	.01
Corn stover.......	1 ton	16.00	2.00	2.42	17.33	3.33	7.00	1.60
Corn cobs........	1 ton	4.00	.....	.....	4.00	.....	.....	.....
Oats, grain.......	1 bu.	.66	.11	.06	.16	.04	.02	.01
Oat straw........	1 ton	12.40	2.00	4.14	20.80	2.80	6.00	1.12
Clover seed.......	1 bu.	1.75	.50	.....	.75	.25	.13	.....
Clover hay.......	1 ton	40.00	5.00	3.28	30.00	7.75	29.25	1.00
Soybean seed.....	1 bu.	3.22	.39	.27	1.26	.15	.14	.....
Soybean hay......	1 ton	43.40	4.74	5.18	35.48	13.84	27.56	.....
Alfalfa hay.......	1 ton	52.08	4.76	5.96	16.64	8.00	22.26	.....

[1]These data are brought together from various sources. Some allowance must be made for the exactness of the figures because samples representing the same kind of crop or the same kind of material frequently exhibit considerable variation.

Table 5 shows the requirements of some of our most common field crops with respect to the seven plant-food elements furnished by the soil. The figures show the weight in pounds of the various elements contained in a bushel or in a ton, as the case may be. From these data the amount of any element removed from an acre of land by a crop of a given yield can easily be computed.

PLANT-FOOD SUPPLY

Of the ten elements of plant food, three (carbon, oxygen, and hydrogen) are secured from air and water, and seven from the soil. Nitrogen, one of these seven elements obtained from the soil by all plants, may also be secured from the air by the class of plants known as legumes, in case the amount liberated from the soil is insufficient; but even these plants, which include only the clovers, peas, beans, and vetches among our common agricultural plants, are dependent upon the soil for the other six elements (phosphorus, potassium, magnesium, calcium, iron, and sulfur), and they also utilize the soil nitrogen so far as it becomes soluble and available during their period of growth.

The vast difference with respect to the supply of these essential plant-food elements in different soils is well brought out in the data of the Illinois soil survey. For example, it has been found that the nitrogen in the surface 6⅔ inches, which represents the plowed stratum, varies in amount from 180 pounds per acre to more than 35,000 pounds. In like manner the phosphorus content varies from about 420 to 4,900 pounds, and the potassium ranges from 1,530 to about 58,000 pounds. Similar variations are found in all of the other essential plant-food elements of the soil.

With these facts in mind it is easy to understand how a deficiency of one of these elements of plant food may become a limiting factor of crop production. When an element becomes so reduced in quantity as to become a limiting factor

TABLE 6.—PLANT-FOOD ELEMENTS IN MANURE, ROUGH FEEDS, AND FERTILIZERS[1]

Material	Pounds of plant food per ton of material		
	Nitrogen	Phosphorus	Potassium
Fresh farm manure	10	2	8
Corn stover	16	2	17
Oat straw	12	2	21
Wheat straw	10	2	18
Clover hay	40	5	30
Cowpea hay	43	5	33
Alfalfa hay	50	4	24
Sweet clover (water-free basis)[2]	80	8	28
Dried blood	280	...	...
Sodium nitrate	310	...	...
Ammonium sulfate	400	...	...
Raw bone meal	80	180	...
Steamed bone meal	20	250	...
Raw rock phosphate	...	250	...
Acid phosphate	...	125	...
Potassium chlorid	...	...	850
Potassium sulfate	...	...	850
Kainit	...	...	200
Wood ashes[3] (unleached)	...	10	100

[1]See footnote to Table 5.
[2]Young second year's growth ready to plow under as green manure.
[3]Wood ashes also contain about 1,000 pounds of lime (calcium carbonate) per ton.

of production, then we must look for some outside source of supply. Table 6 is presented for the purpose of furnishing information regarding the quantity of some of the more important plant-food elements contained in materials most commonly used as sources of supply.

LIBERATION OF PLANT FOOD

The chemical analysis of the soil gives the invoice of plant-food elements actually present in the soil strata sampled and analyzed, but the rate of liberation is governed by many factors, some of which may be controlled by the farmer, while others are largely beyond his control. Chief among the important controllable factors which influence the liberation of plant food are the choice of crops to be grown, the use of limestone, and the incorporation of organic matter. Tillage, especially plowing, also has a considerable effect in this connection.

Feeding Power of Plants.—Different species of plants exhibit a very great diversity in their ability to obtain plant food directly from the insoluble minerals of the soil. As a class, the legumes—especially such biennial and perennial legumes as red clover, sweet clover, and alfalfa—are endowed with unusual power to assimilate from mineral sources such elements as calcium and phosphorus, converting them into available forms for the crops that follow. For this reason it is especially advantageous to employ such legumes in connection with the application of limestone and rock phosphate. Thru their growth and subsequent decay large quantities of the mineral elements are liberated for

the benefit of the cereal crops which follow in the rotation. Moreover, as an effect of the deep-rooting habit of these legumes, mineral plant-food elements are brought up and rendered available from the vast reservoirs of the lower subsoil.

Effect of Limestone.—Limestone corrects the acidity of the soil and supplies calcium, thus encouraging the development not only of the nitrogen-gathering bacteria which live in the nodules on the roots of clover, cowpeas, and other legumes, but also the nitrifying bacteria, which have power to transform the unavailable organic nitrogen into available nitrate nitrogen. At the same time, the products of this decomposition have power to dissolve the minerals contained in the soil, such as potassium and magnesium compounds.

Organic Matter and Biological Action.—Organic matter may be supplied thru animal manures, consisting of the excreta of animals and usually accompanied by more or less stable litter; and by plant manures, including green-manure crops and cover crops plowed under, and also crop residues such as stalks, straw, and chaff. The rate of decay of organic matter depends largely upon its age, condition, and origin, and it may be hastened by tillage. The chemical analysis shows correctly the total organic carbon, which constitutes, as a rule, but little more than half the organic matter; so that 20,000 pounds of organic carbon in the plowed soil of an acre corresponds to nearly 20 tons of organic matter. But this organic matter consists largely of the old organic residues that have accumulated during the past centuries because they were resistant to decay, and 2 tons of clover or cowpeas plowed under may have greater power to liberate plant-food materials than 20 tons of old, inactive organic matter. The history of the individual farm or field must be depended upon for information concerning recent additions of active organic matter, whether in applications of farm manure, in legume crops, or in sods of old pastures.

The condition of the organic matter of the soil is indicated to some extent by the ratio of carbon to nitrogen. Fresh organic matter recently incorporated with the soil contains a very much higher proportion of carbon to nitrogen than do the old resistant organic residues of the soil. The proportion of carbon to nitrogen is higher in the surface soil than in the corresponding subsoil, and in general this ratio is wider in highly productive soils well charged with active organic matter than in very old, worn soils badly in need of active organic matter.

The organic matter furnishes food for bacteria, and as it decays certain decomposition products are formed, including much carbonic acid, some nitrous acid, and various organic acids, and these acting upon the soil have the power to dissolve the essential mineral plant foods, thus furnishing available phosphates, nitrates, and other salts of potassium, magnesium, calcium, etc., for the use of the growing crop.

Effect of Tillage.—Tillage, or cultivation, also hastens the liberation of plant-food elements by permitting the air to enter the soil. It should be remembered, however, that tillage is wholly destructive, in that it adds nothing whatever to the soil, but always leaves it poorer, so far as plant-food materials are concerned. Tillage should be practiced so far as is necessary to prepare a suitable seed bed for root development and also for the purpose of killing weeds, but more than

this is unnecessary and unprofitable; and it is much better actually to enrich the soil by proper applications of limestone, organic matter, and other fertilizing materials, and thus promote soil conditions favorable for vigorous plant growth, than to depend upon excessive cultivation to accomplish the same object at the expense of the soil.

PERMANENT SOIL IMPROVEMENT

According to the kind of soil involved, any comprehensive plan contemplating a permanent system of agriculture will need to take into account some of the following considerations.

The Application of Limestone

The Function of Limestone.—In considering the application of limestone to land it should be understood that this material functions in several different ways, and that a beneficial result may therefore be attributable to quite diverse causes. Limestone provides calcium, of which certain crops are strong feeders. It corrects acidity of the soil, thus making for some crops a much more favorable environment as well as establishing conditions absolutely required for some of the beneficial legume bacteria. It accelerates nitrification and nitrogen fixation. It promotes sanitation of the soil by inhibiting the growth of certain fungous diseases, such as corn-root rot. Experience indicates that it modifies either directly or indirectly the physical structure of fine-textured soils, frequently to their great improvement.

Thus, working in one or more of these different ways, limestone often becomes the key to the improvement of worn lands. Remarkable success has been experienced with limestone used in conjunction with sweet clover in the reclamation of abandoned hill land which has been ruined thru erosion.

Amounts to Apply.—If the soil is acid, limestone should be applied, the initial treatment being at the rate of 2 to 6 tons an acre, according to the degree of acidity. Continue to apply limestone from time to time according to the requirement of the soil as indicated by the tests described below, or until the most favorable conditions are established for the growth of legumes, using preferably at times magnesian limestone ($CaCO_3MgCO_3$), which contains both calcium and magnesium and has slightly greater power to correct soil acidity, ton for ton, than the ordinary calcium limestone ($CaCO_3$). On strongly acid soils, or on land being prepared for alfalfa, 4 or 5 tons per acre of ground limestone may well be used for the first application.

How to Ascertain the Need for Limestone.—One of the most reliable indications as to whether a soil needs limestone is the character of the growth of certain legumes, particularly sweet clover and alfalfa. These crops do not thrive in acid soils. Their successful growth, therefore, indicates the lack of sufficient acidity in the soil to be harmful. In case of their failure to grow the soil should be tested for acidity as described below. A very valuable test for ascertaining the need of a soil for limestone is found in the potassium thiocyanate test for soil acidity. It is desirable to make the test for carbonates along with the acidity test. Limestone is calcium carbonate, while dolomite is the combined carbonate of calcium and magnesium. The natural occurrence of these carbonates in the

soil is sufficient assurance that no limestone is needed, and the acidity test will be negative. On lands which have been treated with limestone, however, the surface soil may give a positive test for carbonates, due to the presence of undecomposed pieces of limestone, and at the same time a positive test for acidity may be secured. Such a result means either that insufficient limestone has been added to neutralize the acidity, or that it has not been in the soil long enough to entirely correct the acidity. In making these tests, it is desirable to examine samples of soil from different depths, since carbonates may be present, even in abundance, below a surface stratum that is acid. Following are the directions for making the tests:

The Potassium Thiocyanate Test for Acidity. This test is made with a 4-percent solution of potassium thiocyanate in alcohol—4 grams of potassium thiocyanate in 100 cubic centimeters of 95-percent alcohol.[1] When a small quantity of soil shaken up in a test tube with this solution gives a red color the soil is acid and limestone should be applied. If the solution remains colorless the soil is not acid. An excess of water interferes with the reaction. The sample when tested, therefore, should be at least as dry as when the soil is in good tillable condition. For a prompt reaction the temperature of the soil and solution should be not lower than that of comfortable working conditions (60° to 75° Fahrenheit).

The Hydrochloric Acid Test for Carbonates. Make a shallow cup of a ball of soil and pour into it a few drops of hydrochloric (muriatic) acid, prepared by diluting the concentrated acid with an equal volume of water. The presence of limestone or some other carbonates will be shown by the appearance of gas bubbles within 2 or 3 minutes, producing foaming or effervescence. The absence of carbonates in a soil is not in itself evidence that the soil is acid or that limestone should be applied, but it indicates that the confirmatory potassium thiocyanate test should be carried out.

The Nitrogen Problem

Nitrogen presents the greatest practical soil problem in American agriculture. Four important reasons for this are: its increasing deficiency in most soils; its cost when purchased on the open market; its removal in large amounts by crops; and its loss from soils thru leaching. Nitrogen usually costs from four to five times as much per pound as phosphorus. A 100-bushel crop of corn requires 150 pounds of nitrogen for its growth, but only 23 pounds of phosphorus. The loss of nitrogen from soils may vary from a few pounds to over one hundred pounds per acre, depending upon the treatment of the soil, the distribution of rainfall, and the protection afforded by growing crops.

An inexhaustible supply of nitrogen is present in the air. Above each acre of the earth's surface there are about sixty-nine million pounds of atmospheric nitrogen. The nitrogen above one square mile weighs twenty million tons, an amount sufficient to supply the entire world for four or five decades. This large supply of nitrogen in the air is the one to which the world must eventually turn.

There are two methods of collecting the inert nitrogen gas of the air and combining it into compounds that will furnish products for plant growth. These are the chemical and the biological fixation of the atmospheric nitrogen. Farmers have at their command one of these methods. By growing inoculated legumes, nitrogen may be obtained from the air, and by plowing under more than the roots of those legumes, nitrogen may be added to the soil.

Inasmuch as legumes are worth growing for purposes other than the fixation of atmospheric nitrogen, a considerable portion of the nitrogen thus gained

[1] Since undenatured alcohol is difficult to obtain, some of the denatured alcohols have been tested for making this solution. Completely denatured alcohol made over U. S. Formulas No. 1 and No. 4_1, have been found satisfactory. Some commercial firms are also offering similar preparations which are quite satisfactory.

may be considered a by-product. Because of that fact, it is questionable whether the chemical fixation of nitrogen will ever be able to replace the simple method of obtaining atmospheric nitrogen by growing inoculated legumes in the production of our great grain and forage crops.

It may well be kept in mind that the following amounts of nitrogen are required for the produce named:

1 bushel of oats (grain and straw) requires 1 pound of nitrogen.
1 bushel of corn (grain and stalks) requires 1½ pounds of nitrogen.
1 bushel of wheat (grain and straw) requires 2 pounds of nitrogen.
1 ton of timothy contains 24 pounds of nitrogen.
1 ton of clover contains 40 pounds of nitrogen.
1 ton of cowpea hay contains 43 pounds of nitrogen.
1 ton of alfalfa contains 50 pounds of nitrogen.
1 ton of average manure contains 10 pounds of nitrogen.
1 ton of young sweet clover, at about the stage of growth when it is plowed under as green manure, contains, on water-free basis, 80 pounds of nitrogen.

The roots of clover contain about half as much nitrogen as the tops, and the roots of cowpeas contain about one-tenth as much as the tops. Soils of moderate productive power will furnish as much nitrogen to clover (and two or three times as much to cowpeas) as will be left in the roots and stubble. In grain crops, such as wheat, corn, and oats, about two-thirds of the nitrogen is contained in the grain and one-third in the straw or stalks.

The Phosphorus Problem

The element phosphorus is an indispensable constituent of every living cell. It is intimately connected with the life processes of both plants and animals, the nuclear material of the cells being especially rich in this element.

The phosphorus content of the soil is dependent upon the origin of the soil. The removal of phosphorus by continuous cropping slowly reduces the amount of this element in the soil available for crop use, unless its addition is provided for by natural means, such as overflow, or by agricultural practices, such as the addition of phosphatic fertilizers and rotations in which deep-footing, leguminous crops are frequently grown.

It should be borne in mind in connection with the application of phosphate, or of any other fertilizing material, to the soil, that no benefit can result until the need for it has become a limiting factor in plant growth. For example, if there is already present in the soil sufficient available phosphorus to produce a forty-bushel crop, and the nitrogen supply or the moisture supply is sufficient for only forty bushels, or less, then extra phosphorus added to the soil cannot increase the yield beyond this forty-bushel limit.

There are several different materials containing phosphorus which are applied to land as fertilizer. The more important of these are bone meal, acid phosphate, natural raw rock phosphate, and basic slag. Obviously that carrier of phosphorus which gives the most economical returns, as considered from all standpoints, is the most suitable one to use. Altho this matter has been the subject of much discussion and investigation the question still remains unsettled. Probably there is no single carrier of phosphorus that will prove to be the most economical one to use under all circumstances because so much depends upon soil conditions, crops grown, length of haul, and market conditions.

Bone meal, prepared from the bones of animals, appears on the market in two different forms, raw and steamed. Raw bone meal contains, besides the phosphorus, a considerable percentage of nitrogen which adds a useless expense if the material is purchased only for the sake of the phosphorus. As a source of phosphorus, steamed bone meal is preferable to raw bone meal. Steamed bone meal is prepared by extracting most of the nitrogenous and fatty matter from the bones, thus producing a more nearly pure form of calcium phosphate containing about 10 to 12 percent of the element phosphorus.

Acid phosphate is produced by treating rock phosphate with sulfuric acid. The two are mixed in about equal amounts; the product therefore contains about one-half as much phosphorus as the rock phosphate itself. Besides phosphorus, acid phosphate also contains sulfur, which is likewise an element of plant food. The phosphorus in acid phosphate is more readily available for absorption by plants than that of raw rock phosphate. Acid phosphate of good quality should contain 6 percent or more of the element phosphorus.

Rock phosphate, sometimes called floats, is a mineral substance found in vast deposits in certain regions. The phosphorus in this mineral exists chemically as tri-calcium phosphate and a good grade of the rock should contain 12½ percent, or more, of the element phosphorus. The rock should be ground to a powder, fine enough to pass thru a 100-mesh sieve, or even finer.

The relative cheapness of raw rock phosphate, as compared with the treated or acidulated material, makes it possible to apply for equal money expenditure considerably more phosphorus per acre in this form than in the form of acid phosphate, the ratio being, under the market conditions of the past several years, about 4 to 1. That is to say, under these market conditions, a dollar will purchase about four times as much of the element phosphorus in the form of rock phosphate as in the form of acid phosphate, which is an important consideration if one is interested in building up a phosphorus reserve in the soil. As explained above, more very carefully conducted comparisons on various soil types under various cropping systems are needed before definite statements can be given as to which form of phosphate is most economical to use under any given set of conditions.

Basic slag, known also as Thomas phosphate, is another carrier of phosphorus that might be mentioned because of its considerable usage in Europe and eastern United States. Basic slag phosphate is a by-product in the manufacture of steel. It contains a considerable proportion of basic material and therefore it tends to influence the soil reaction.

Rock phosphate may be applied at any time during a rotation, but it is applied to the best advantage either preceding a crop of clover, which plant seems to possess an unusual power for assimilating the phosphorus from raw phosphate, or else at a time when it can be plowed under with some form of organic matter such as animal manure or green manure, the decay of which serves to liberate the phosphorus from its insoluble condition in the rock. It is important that the finely ground rock phosphate be intimately mixed with the organic material as it is plowed under.

In using acid phosphate or bone meal in a cropping system which includes wheat, it is a common practice to apply the material in the preparation of the

wheat ground. It may be advantageous, however, to divide the total amount to be used and apply a portion to the other crops of the rotation, particularly to corn and to clover.

The Potassium Problem

Our most common soils, which are silt loams and clay loams, are well stocked with potassium, altho it exists largely in a slowly soluble form. Such soils as sands and peats, however, are likely to be low in this element. On such soils this deficiency may be remedied by the application of some potassium salt, such as potassium sulfate, potassium chlorid, kainit, or other potassium compound, and in many instances this is done at great profit.

From all the facts at hand it seems, so far as our great areas of common soils are concerned, that, with a few exceptions, the potassium problem is not one of addition but of liberation. The Rothamsted records, which represent the oldest soil experiment fields in the world, show that for many years other soluble salts have had practically the same power as potassium salts to increase crop yields in the absence of sufficient decaying organic matter. Whether this action relates to supplying or liberating potassium for its own sake, or to the power of the soluble salt to increase the availability of phosphorus or other elements, is not known, but where much potassium is removed, as in the entire crops at Rothamsted, with no return of organic residues, probably the soluble salt functions in both ways.

Further evidence on this matter is furnished by the Illinois experiment field at Fairfield, where potassium sulfate has been compared with kainit both with and without the addition of organic matter in the form of stable manure. Both sulfate and kainit produced a substantial increase in the yield of corn, but the cheaper salt—kainit—was just as effective as the potassium sulfate, and returned some financial profit. Manure alone gave an increase similar to that produced by the potassium salts, but the salts added to the manure gave very little increase over that produced by the manure alone. This is explained in part, perhaps, by the fact that the potassium removed in the crops is mostly returned in manure properly cared for, and perhaps in larger part by the fact that decaying organic matter helps to liberate and hold in solution other plant-food elements, especially phosphorus.

In laboratory experiments at the Illinois Experiment Station, it has been shown that potassium salts and most other soluble salts increase the solubility of the phosphorus in soil and in rock phosphate; also that the addition of glucose with rock phosphate in pot-culture experiments increases the availability of the phosphorus, as measured by plant growth, altho the glucose consists only of carbon, hydrogen, and oxygen, and thus contains no limiting element of plant food.

In considering the conservation of potassium on the farm it should be remembered that in average live-stock farming, the animals destroy two-thirds of the organic matter and retain one-fourth of the nitrogen and phosphorus from the food they consume, but that they retain less than one-tenth of the potassium; so that the actual loss of potassium in the products sold from the farm, either in grain farming or in livestock farming, is negligible on land containing 25,000 pounds or more of potassium in the surface 6⅔ inches.

The Calcium and Magnesium Problem

When measured by crop removals of the plant-food elements, calcium is often more limited in Illinois soils than is potassium, while magnesium may be occasionally. In the case of calcium, however, the deficiency is likely to develop more rapidly and become much more marked because this element is leached out of the soil in drainage water to a far greater extent than is either magnesium or potassium.

The annual loss of limestone from the soil depends, of course, upon a number of factors aside from those which have to do with climatic conditions. Among these factors may be mentioned the character of the soil, the kind of limestone, its condition of fineness, the amount present, and the sort of farming practiced. Because of this variation in the loss of lime materials from the soil, it is impossible to prescribe a fixed practice in their renewal that will apply universally. The tests for acidity and carbonates described above, together with the behavior of such lime-loving legumes as alfalfa and sweet clover, will serve as general indicators for the frequency of applying limestone and the amount to use on a given field.

Limestone has a positive value on some soils for the plant food which it supplies, in addition to its value in correcting soil acidity and in improving the physical condition of the soil. Ordinary limestone (abundant in the southern and western parts of the state) contains nearly 800 pounds of calcium per ton; while a good grade of dolomitic limestone (the more common limestone of northern Illinois) contains about 400 pounds of calcium and 300 pounds of magnesium per ton. Both of these elements are furnished in readily available form in ground dolomitic limestone.

The Sulfur Question

In considering the relation of sulfur in a permanent system of soil fertility it is important to understand something of the cycle of transformations that this element undergoes in nature. Briefly stated this is as follows:

Sulfur exists in the soil in both organic and inorganic forms, the former being gradually converted to the latter form thru bacterial action. In this inorganic form sulfur is taken up by plants which in their physiological processes change it once more into an organic form as a constituent of protein. When these plant proteins are consumed by animals, the sulfur becomes a part of the animal protein. When these plant and animal proteins are decomposed, either thru bacterial action, or thru combustion, as in the burning of coal, the sulfur passes into the atmosphere or into the soil solution in the form of sulfur dioxid gas. This gas unites with oxygen and water to form sulfuric acid, which is readily washed back into the soil by the rain, thus completing the cycle, from soil—to plants and animals—to air—to soil.

In this way sulfur becomes largely a self-renewing element of the soil, altho there is a considerable loss from the soil by leaching. Observations taken at the Illinois Agricultural Experiment Station show that 40 pounds of sulfur per acre are brought into the soil thru the annual rainfall. With a fair stock of sulfur, such as exists in our common types of soil, and with an annual return,

which of itself would more than suffice for the needs of maximum crops, the maintenance of an adequate sulfur supply presents little reason at present for serious concern. There are regions, however, where the natural stock of sulfur in the soil is not nearly so high and where the amount returned thru rainfall is small. Under such circumstances sulfur soon becomes a limiting element of crop production, and it will be necessary sooner or later to introduce this substance from some outside source. Investigation is now under way to determine to what extent this situation may apply to conditions in Illinois.

Physical Improvement of Soils

In the management of most soil types, one very important matter, aside from proper fertilization, tillage, and drainage, is to keep the soil in good physical condition, or good tilth. The constituent most important for this purpose is organic matter. Organic matter in producing good tilth helps to control washing of soil on rolling land, raises the temperature of drained soil, increases the moisture-holding capacity of the soil, slightly retards capillary rise and consequently loss of moisture by surface evaporation, and helps to overcome the tendency of some soils to run together badly.

The physical effect of organic matter is to produce a granulation or mellowness, by cementing the fine soil particles into crumbs or grains about as large as grains of sand, which produces a condition very favorable for tillage, percolation of rainfall, and the development of plant roots.

Organic matter is undergoing destruction during a large part of the year and the nitrates produced in its decomposition are used for plant growth. Altho this decomposition is necessary, it nevertheless reduces the amount of organic matter, and provision must therefore be made for maintaining the supply. The practical way to do this is to turn under the farm manure, straw, cornstalks, weeds, and all or part of the legumes produced on the farm. The amount of legumes needed depends upon the character of the soil. There are farms, especially grain farms, in nearly every community where all legumes could be turned under for several years to good advantage.

Manure should be spread upon the land as soon as possible after it is produced, for if it is allowed to lie in the barnyard several months as is so often the case, from one-third to two-thirds of the organic matter will be lost.

Straw and cornstalks should be turned under, and not burned. There is considerable evidence indicating that on some soils undecomposed straw applied in excessive amount may be detrimental. Probably the best practice is to apply the straw as a constituent of well-rotted stable manure. Perhaps no form of organic matter acts more beneficially in producing good tilth than cornstalks. It is true, they decay rather slowly, but it is also true that their durability in the soil is exactly what is needed in the production of good tilth. Furthermore, the nitrogen in a ton of cornstalks is one and one-half times that of a ton of manure, and a ton of dry cornstalks incorporated in the soil will ultimately furnish as much humus as four tons of average farm manure. When burned, however, both the humus-making material and the nitrogen are lost to the soil.

It is a common practice in the corn belt to pasture the cornstalks during the winter and often rather late in the spring after the frost is out of the ground.

This trampling by stock sometimes puts the soil in bad condition for working. It becomes partially puddled and will be cloddy as a result. If tramped too late in the spring, the natural agencies of freezing and thawing and wetting and drying, with the aid of ordinary tillage, fail to produce good tilth before the crop is planted. Whether the crop is corn or oats, it necessarily suffers, and if the season is dry, much damage may be done. If the field is put in corn, a poor stand is likely to result, and if put in oats, the soil is so compact as to be unfavorable for their growth. Sometimes the soil is worked when too wet. This also produces a partial puddling which is unfavorable to physical, chemical, and biological processes. The effect becomes worse if cropping has reduced the organic matter below the amount necessary to maintain good tilth.

Systems of Crop Rotations

In a program of permanent soil improvement one should adopt at the outset a good rotation of crops, including, for the reasons discussed above, a liberal use of legumes. No one can say in advance for every particular case what will prove to be the best rotation of crops, because of variation in farms and farmers and in prices for produce.

Following are a few suggested rotations, applicable to the corn belt, which may serve as models or outlines to be modified according to special circumstances.

Six-Year Rotations

First year —Corn
Second year —Corn
Third year —Wheat or oats (with clover, or clover and grass)
Fourth year —Clover, or clover and grass
Fifth year —Wheat (with clover), or grass and clover
Sixth year —Clover, or clover and grass

Of course there should be as many fields as there are years in the rotation. In grain farming, with small grain grown the third and fifth years, most of the unsalable products should be returned to the soil, and the clover may be clipped and left on the land or returned after threshing out the seed (only the clover seed being sold the fourth and sixth years); or, in livestock farming, the field may be used three years for timothy and clover pasture and meadow if desired. The system may be reduced to a five-year rotation by cutting out either the second or the sixth year, and to a four-year system by omitting the fifth and sixth years, as indicated below.

Five-Year Rotations

First year —Corn
Second year —Wheat or oats (with clover, or clover and grass)
Third year —Clover, or clover and grass
Fourth year —Wheat (with clover), or clover and grass
Fifth year —Clover, or clover and grass

First year —Corn
Second year —Corn
Third year —Wheat or oats (with clover, or clover and grass)
Fourth year —Clover, or clover and grass
Fifth year —Wheat (with clover)

First year —Corn
Second year —Cowpeas or soybeans
Third year —Wheat (with clover)
Fourth year —Clover
Fifth year —Wheat (with clover)

The last rotation mentioned above allows legumes to be grown four times. Alfalfa may be grown on a sixth field for five or six years in the combination rotation, alternating between two fields every five years, or rotating over all the fields if moved every six years.

Four-Year Rotations

First year —Corn
Second year —Wheat or oats (with clover)
Third year —Clover
Fourth year —Wheat (with clover)

First year —Corn
Second year —Corn
Third year —Wheat or oats (with clover)
Fourth year —Clover

First year —Corn
Second year —Cowpeas or soybeans
Third year —Wheat (with clover)
Fourth year —Clover

First year —Wheat (with clover)
Second year —Clover
Third year —Corn
Fourth year —Oats (with clover)

Alfalfa may be grown on a fifth field for four or eight years, which is to be alternated with one of the four; or the alfalfa may be moved every five years, and thus rotated over all five fields every twenty-five years.

Three-Year Rotations

First year —Corn
Second year —Oats or wheat (with clover)
Third year —Clover

First year —Wheat (with clover)
Second year —Corn
Third year —Cowpeas or soybeans

By allowing the clover, in the last rotation mentioned, to grow in the spring before preparing the land for corn, we have provided a system in which legumes grow on every acre every year. This is likewise true of the following suggested two-year system:

Two-Year Rotations

First year —Oats or wheat (with sweet clover)
Second year —Corn

Altho in this two-year rotation either oats or wheat is suggested, as a matter of fact, by dividing the land devoted to small grain, both of these crops can be grown simultaneously, thus providing a three-crop system in a two-year cycle.

It should be understood that in all of the above suggested cropping systems it may be desirable in some cases to substitute rye for the wheat or oats. Or, in some cases, it may become desirable to divide the acreage of small grain and grow in the same year more than one kind. In all of these proposed rotations the word *clover* is used in a general sense to designate either red clover, alsike clover, or sweet clover. The value of sweet clover, especially as a green manure for building up depleted soils, as well as a pasture and haycrop, is becoming thoroly established, and its importance in a crop-rotation program may well be emphasized.

SUPPLEMENT: EXPERIMENT FIELD DATA

(Results from Experiment Fields on Soil Types Similar to those Occurring in Johnson County)

In the earlier reports of this series it was the practice to incorporate in the body of the report the results from certain experiment fields, for the purpose of illustrating the possibilities of improving the soil of various types. The information carried by such data must, naturally, be considered more or less tentative. As the fields grow older new facts develop, which in some instances may call for the modification of former recommendations. It has therefore seemed desirable to separate this experiment field data from the more permanent information of the soil survey, and embody the same in the form of a supplement to the soil report proper, thus providing a convenient arrangement for possible future revisions as further data accumulate.

The University of Illinois has operated altogether about fifty soil experiment fields in different sections of the state and on various types of soil. Altho some of these fields have been discontinued, the majority are still in operation. It is the present purpose to report the summarized results from certain of these fields located on types of soil described in the accompanying soil report.

A few general explanations at this point, which apply to all the fields, will relieve the necessity of numerous repetitions in the following pages.

Size and Arrangement of Fields

The soil experiment fields vary in size from less than two acres up to 40 acres or more. They are laid off into series of plots, the plots commonly being either one-fifth or one-tenth acre in area. Each series is occupied by one kind of crop. Usually there are several series so that a crop rotation can be carried on with every crop represented every year.

Two Farming Systems Provided

On many of the fields the treatment provides for two distinct systems of farming, livestock farming and grain farming.

In the livestock system, stable manure is used to furnish organic matter and nitrogen. The amount applied to a plot is based upon the amount that can be produced from crops raised on that plot.

In the grain system no animal manure is used. The organic matter and nitrogen are applied in the form of plant manures, including the plant residues produced, such as corn stalks, straw from wheat, oats, clover, etc., along with leguminous catch crops plowed under. It is the plan in this latter system to remove from the land, in the main, only the grain and seed produced, except in the case of alfalfa, that crop being harvested for hay the same as in the livestock system.

Definite Crop Rotations Followed

Crops which are of interest in the respective localities are grown in definite rotations. The most common rotation used is wheat, corn, oats, and clover; and often these crops are accompanied by alfalfa growing on a fifth series. In the grain system a legume catch crop, usually sweet clover, is included, which is seeded on the young wheat in the spring and plowed under in the fall or in the following spring in preparation for corn. If the red clover crop fails, soybeans are substituted.

Standard Soil Treatment Used

The treatment applied to the plots has, for the most part, been standardized according to a rather definite system, altho deviations from this system occur now and then, particularly in the older fields.

Following is a brief explanation of this standard system of treatment.

Animal Manures.—Animal manures, consisting of excreta from animals, with stable litter, are spread upon the respective plots in amounts proportionate to previous crop yields, the applications being made in the preparation for corn.

Plant Manures.—Crop residues produced on the land, such as stalks, straw, and chaff, are returned to the soil, and in addition a green-manure crop of sweet clover is seeded in small grain to be plowed under in preparation for corn. (On plots where limestone is lacking the sweet clover seldom survives.) This practice is designated as the *residues system.*

Mineral Manures.—The yearly acre-rates of application have been: for limestone, 1,000 pounds; for raw rock phosphate, 500 pounds; and for potassium, usually 200 pounds of kainit. When kainit was not available, owing to conditions brought on by the World war, potassium carbonate was used. The initial application of limestone has usually been 4 tons per acre.

Explanation of Symbols

0 = Untreated land or check plots
M = Manure (animal)
R = Residues (from crops, and includes legumes used as green manure)
L = Limestone
P = Phosphorus
K = Potassium (usually in the form of kainit)
N = Nitrogen (usually in the form contained in dried blood)
( ) = Parentheses enclosing figures signify tons of hay, as distinguished from bushels of seed

In discussions of this sort of data, financial profits or losses based upon assigned market values are frequently considered. However, in view of the erratic fluctuations in market values—especially in the past few years—it seems futile to attempt to set any prices for this purpose that are at all satisfactory. The yields are therefore presented with the thought that with these figures at hand the financial returns from a given practice can readily be computed upon the basis of any set of market values that the reader may choose to apply.

THE OLD VIENNA FIELD

From 1902 to 1911 the University conducted an experiment field in Johnson county, about two miles southeast of Vienna, on land that was described at the time as "red clay, a soil typical of the hill sections of the state." The field comprized a tract of 5.6 acres of land rolling in topography, a portion of which was low and wet. It was not tile-drained.

Previous to 1902 this land had been cultivated for about fifty years, after which it was said to be still capable of producing fair crops of corn and wheat.

For the experiment work the field was laid out into three series of plots one-fifth acre in size, each series containing 5 plots. A crop rotation of wheat, corn, and cowpeas was started; but in 1905 this rotation was changed to corn, oats, wheat, and legumes. Cowpeas for plowing down were seeded in the corn at the last cultivation excepting on Plot 1. As the carrier of phosphorus, steamed bone meal was used at the rate of 200 pounds an acre a year. Potassium was applied in the form of potassium sulfate, this material being used at the annual acre rate of 100 pounds. Lime was applied in 1902 in the form of slaked lime at the rate of 1,800 pounds, and the following year limestone was added at the rate of 8 tons.

The results of these treatments are presented in Table 7, which records for each year the acre yields of all crops harvested. Table 8 presents a summary giving the average annual acre yields of the 9 corn crops and 8 wheat crops harvested after the plots had received their respective treatments.

The great need of this land for organic matter and nitrogen is brought out in these results. Organic matter and nitrogen are furnished by the legumes in

TABLE 7.—OLD VIENNA FIELD

Annual Crop Yields—Bushels or (tons) per acre

Plot No.	Soil treatment applied	1902 Corn[1]	1903 Corn	1904 Cowpeas	1905 Wheat	1906 Cowpeas[2]	1907 Corn	1908 Wheat	1909 Cowpeas[4]	1910 Corn	1911 Cowpeas
101	0..........	15.5	9.3	Removed	1.3	....	16.7	.0	....	33.5	Removed
102	Le..........	13.3	5.0	Turned	10.8	....	17.8	.0	....	35.4	Turned
103	LeL........	14.9	8.3	Turned	18.2	....	30.3	4.5	....	44.7	Turned
104	LeLP.......	12.5	7.4	Turned	25.6	....	37.1	8.3	....	46.6	Turned
105	LeLPK.....	19.9	11.6	Turned	30.0	....	38.1	9.8	....	58.3	Turned
		Oats[1]	Cowpeas[1]	Wheat	Corn	Wheat	Clover	Corn	Wheat	Clover	Corn
201	0..........	19.1	Removed	6.7	37.5	3.8	(.65)	35.2	4.6	(.26)	34.2
202	Le..........	18.8	Turned	7.1	42.9	5.4	(.81)	35.6	6.8	(.04)	30.8
203	LeL........	19.8	Turned	10.0	61.9	17.9	(1.92)	43.9	9.6	(1.45)	38.8
204	LeLP.......	20.0	Turned	14.8	57.2	11.3	(2.56)	42.9	12.8	(1.85)	23.4[5]
205	LeLPK.....	31.7	Turned	17.5	56.5	15.0	(2.23)	50.6	11.3	(2.19)	32.0[5]
		Cowpeas[1]	Wheat	Corn	Cowpeas	Corn	Wheat	Cowpeas[4]	Corn	Wheat	Clover
301	0..........	Removed	.4	30.5	Removed	41.2	4.3	....	23.0	3.1	(.13)[3]
302	Le..........	Turned	.6	35.5	Turned	40.6	6.1	....	24.9	8.7	(.16)
303	LeL........	Turned	.7	49.1	Turned	48.9	13.0	....	31.3	13.5	(.97)
304	LeLP.......	Turned	8.0	49.4	Turned	40.9	13.6	....	32.6	14.4	(.92)
305	LeLPK.....	Turned	11.0	44.7	Turned	40.9	15.6	....	33.5	14.6	(.98)

[1] No legume treatment.
[2] Through error the growth was removed from the plots but not weighed.
[3] Hay very weedy.
[4] The pods were harvested but not weighed by plots.
[5] Very poor stand, due to moles.

these experiments; but in order to produce a thrifty growth of legumes, it was necessary to apply lime. Thus, upon the addition of limestone, the corn yield was increased by one-third, while the wheat yield was practically doubled. In the case of the corn, little or no effect was produced by the addition of either phosphorus or potassium treatment. In the wheat, however, an increase of

TABLE 8.—OLD VIENNA FIELD: SUMMARY OF THE GRAIN CROPS
Average Annual Yields, 1903-1911—Bushels per acre

Soil treatment	Corn *9 crops*	Wheat *8 crops*
0	29.0	3.0
Le	29.8	5.7
LeL	39.7	10.9
LeLP	37.5	13.6
LeLPK	40.7	15.6

about 3 bushels an acre a year appears upon the addition of phosphorus, and a further increase of 2 bushels an acre a year upon including potassium in the treatment.

The yields from the three clover crops are not summarized, but an inspection of the individual results in Table 7 shows some very fair yields of clover on the better treated plots.

Altho these results furnish an indication of the most important needs of this land, it cannot be said that the experiments as conducted represent directly an economical system of farming. Considering the several years in which the land was given over to the growth of a green manure crop when nothing was harvested, even the yields from the best plots would scarcely be sufficient to cover the cost of maintenance. However, it appears possible that by modifying the cropping plan in some manner, as for example, substituting sweet clover for cowpeas and giving large place in the farming system to hay and pasture crops, the yields might be substantially increased and thus a system of farming instituted that would represent a profitable enterprise.

THE NEW VIENNA FIELD

From 1906 to 1924 another experiment field, designated as the new Vienna field, was maintained. This field was located about a mile southeast of Vienna and about a half-mile west of the old Vienna field described above. It embraced 16 acres of the badly eroded hilly land characteristic of the region.

The soil of this field is, in general, of loessial formation. It is strongly acid in reaction. Altho the soil type appears on the county map as Yellow Silt Loam, a detailed examination of the area occupied by the field discloses on a larger-scaled map three separable types, namely, Yellow Silt Loam, Yellow-Gray Silt Loam, and Deep Gray Silt Loam. (See Fig. 6.)

The work on this field from 1906 to 1915 was concerned with an investigation of methods of reclaiming this land primarily thru means of reducing erosion. Before taking over the field, the land, with the exception of about three acres, had been abandoned because so much of the surface soil had been washed away, and gulleying had become so bad that further cultivation was unprofit-

able. Some of the gulleys were four or five feet deep, so that the first step in reclaiming the land was to fill them and thus make the slopes more uniform.

Experiments in Reducing Erosion

The field was divided into five sections. The sections designated as A, B, and C were divided into 4 plots each, and D into 3 plots. On section A, which included the steepest part of the area and contained many gullies, the land was built up into terraces at vertical intervals of five feet. Near the edge of each terrace a small ditch was placed so that the water could be carried to a natural outlet without much washing.

On section B the so-called embankment method was used. By this method erosion is prevented by plowing up ridges sufficiently high so that if the water breaks over, it will run over in a broad sheet rather than in narrow channels. At the steepest part of the slope, hillside ditches were made for carrying away the run-off.

Section C was washed badly but contained only small gullies. Here the attempt was made to prevent washing by incorporating organic matter in the soil and practicing deep contour plowing and contour planting. With two exceptions, about eight loads of manure an acre were turned under each year for the corn crop.

The land on section D was washed to about the same extent as that of section C. As a check on the different methods of reducing erosion, the land on Section D was farmed in the most convenient way, without any special effort being made to prevent washing.

Section E was badly eroded and gullied and no attempt was made to crop it other than to fill in the gullies with brush and to seed the land to grass.

Sections A, B, C, and D were not entirely uniform; some parts were washed more than others and portions of the lower-lying land had been affected by soil material washed down from above. When the field was secured, the higher land had a very low producing capacity. On many spots little or nothing would grow.

Limestone was applied to the entire field at the rate of 2 tons an acre. Corn, cowpeas, wheat, and clover were grown in a four-year rotation on each section excepting D which had but three plots.

Table 9 contains a summarized statement of the results obtained. For a more detailed account of this work the reader is referred to Bulletin 207 of this Station entitled "Washing of Soils and Methods of Prevention."

TABLE 9.—NEW VIENNA FIELD: HANDLING HILLSIDE LAND TO PREVENT EROSION
Average Annual Yields, 1907-1915—Bushels or (tons) per acre

Section	Method	Corn *7 crops*	Wheat *7 crops*	Clover *3 crops*
A	Terrace	31.4	9.0	(.68)
B	Embankments and hillside ditches	32.4	12.7	(.97)
C	Organic matter, deep contour plowing, and contour planting	27.9	11.7	(.80)
D	Check	14.1	4.6	(.21)

FIG. 4.—AN UNIMPROVED HILLSIDE OVER THE FENCE FROM THE FIELD SHOWN IN FIG. 5

These results indicate something of the possibilities in improving hillside land by protecting it from erosion. The average yield of corn from the protected series (A, B, and C) was 30.6 bushels an acre, as against 14.1 bushels for series D; wheat yielded 11.1 bushels in comparison with 4.6 bushels; and clover .82 ton in comparison with .21 ton.

A comparison of Figs. 1 and 2 will serve to indicate the possibility of improving this type of soil.

Later Experiments on the New Vienna Field

Upon discontinuing the above described work on the prevention of washing, an experiment in cropping and fertilizing was begun in 1916 in which the main

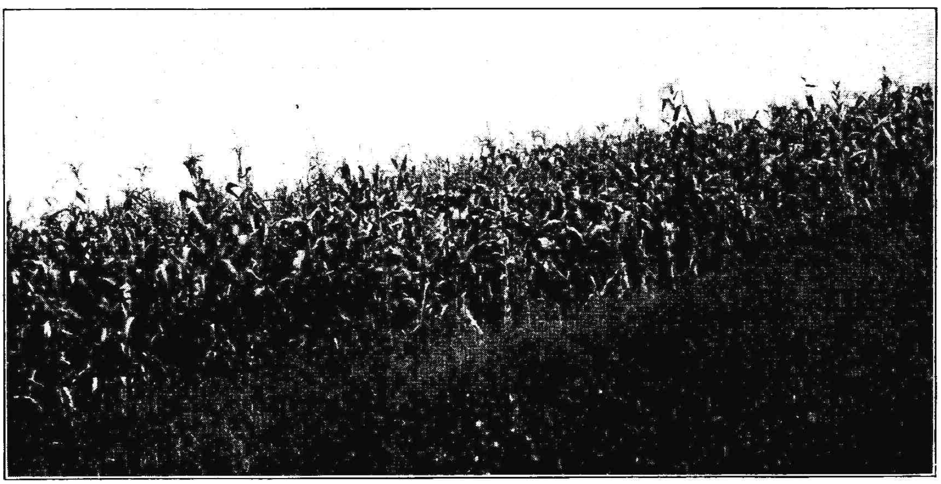

FIG. 5.—CORN GROWING ON IMPROVED HILLSIDE OF THE VIENNA EXPERIMENT FIELD. THIS LAND FORMERLY HAD BEEN BADLY ERODED. COMPARE WITH FIG. 4.

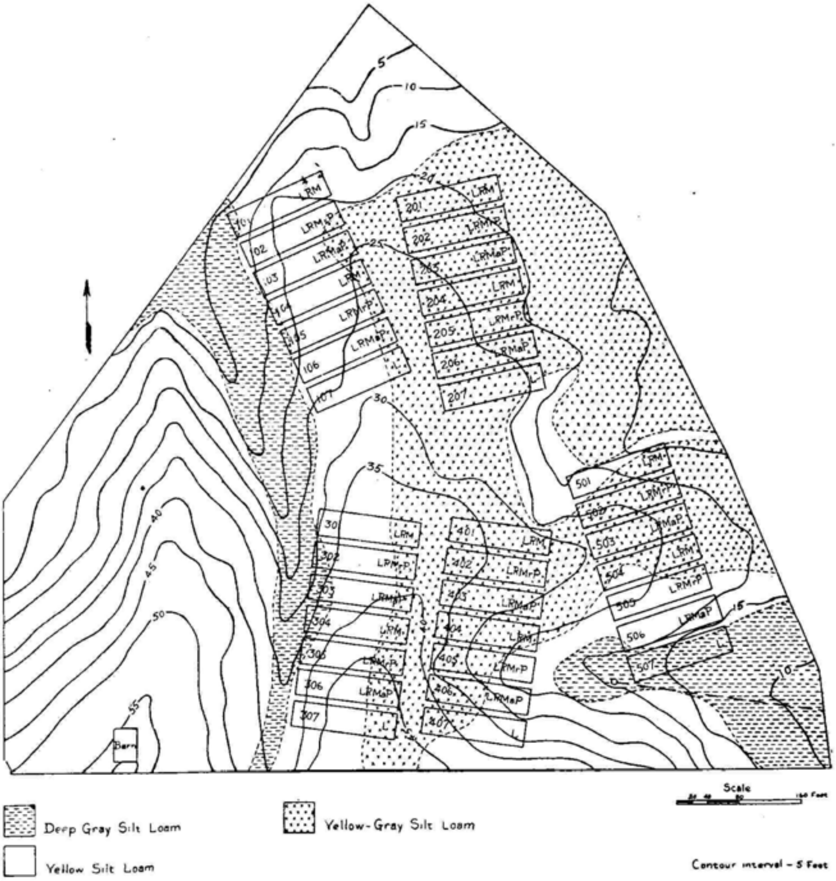

FIG. 6.—SOIL MAP OF VIENNA FIELD

feature was a comparison of the relative efficiency of rock phosphate and acid phosphate. For this purpose the land was re-plotted into five series distributed over the field as shown in the accompanying map (Fig. 6). Each series was made up of seven tenth-acre plots which were treated as indicated on the map and in Table 10.

A crop rotation was used which included corn, cowpeas, wheat (seeded to timothy), clover, (with timothy), and timothy.

About 4 tons of limestone an acre was applied to all plots in the fall of 1915, and this was followed by 2 tons an acre each rotation thereafter. The rock phosphate was applied at the rotation rate of one ton an acre in three equal applications, in preparation for corn, for cowpeas, and for wheat. The acid phosphate was applied in the same manner except that only a half-ton an acre was used for each rotation. The crop residues plowed under were for the most part cornstalks. The stalks were rolled down so that they lay at right angles to the slope of the ground. The manure was applied in amounts equivalent to the total weight of all the produce (excepting the cornstalks) removed from the respective plots.

The results of this investigation are recorded in Table 10, which gives the annual acre yields of the respective crops thruout the nine years of the work.

A careful scrutiny of these results reveals something of the difficulties in deriving definite conclusions with respect to the questions that the experiments were designed to answer, but an inspection of the accompanying map of the New Vienna field will explain why some of these difficulties exist. The interpretation of experiment field results, even with land of level topography, almost always presents some difficulties arising from the variation in natural productiveness of the plots. On land of such rough topography as the new Vienna field

TABLE 10.—NEW VIENNA FIELD: ROTATION—CORN, COWPEAS, WHEAT, CLOVER, TIMOTHY
Annual Crop Yields—Bushels or (tons) per acre

Plot No.	Soil treatment applied	1916 Corn	1917 Cowpeas	1918 Wheat	1919 Clover	1920 Timothy	1921 Corn	1922 Cowpeas	1923 Wheat	1924 Clover
101	LRM........	10.0	6.2	17.3	(3.46)	(1.30)	24.8	8.8	22.2	(2.52)
102	LRM rP.....	5.0	6.3	22.0	(2.85)	(1.25)	27.4	9.1	23.2	(2.64)
103	LRM aP....	10.9	4.9	25.5	(3.03)	(1.55)	23.5	5.7	27.2	(2.96)
104	LRM........	12.1	4.0	22.5	(2.84)	(1.35)	25.5	7.2	25.3	(2.51)
105	LRM rP.....	10.3	4.0	16.5	(2.65)	(1.00)	24.6	6.0	21.6	(2.54)
106	LRM aP....	11.9	4.0	22.5	(2.27)	(1.50)	27.8	3.6	24.0	(2.76)
107	L...........	11.6	7.8	14.2	(1.87)	(1.00)	22.8	8.8	12.3	(1.29)
		Cowpeas	Wheat	Clover	Timothy	Corn	Cowpeas	Wheat	Clover	Timothy
201	LRM........	7.8	15.3	(2.10)	(2.93)	50.0	32.0	27.9	(1.89)	(1.60)
202	LRM rP.....	9.9	17.8	(2.40)	(3.20)	54.5	33.1	30.1	(2.57)	(1.83)
203	LRM aP....	8.8	19.5	(1.97)	(3.53)	52.8	30.0	31.1	(2.51)	(1.71)
204	LRM........	9.8	18.3	(2.00)	(3.30)	57.1	29.8	30.3	(1.88)	(1.66)
205	LRM rP.....	9.6	17.3	(2.30)	(3.01)	54.0	28.5	29.8	(2.59)	(1.73)
206	LRM aP....	9.2	12.8	(2.40)	(3.45)	48.9	26.3	26.9	(2.15)	(1.51)
207	L...........	8.9	6.5	(1.43)	(2.65)	44.2	18.0	14.9	(1.43)	(.87)
		Wheat	Clover	Timothy	Corn	Cowpeas	Wheat	Clover	Timothy	Corn
301	LRM........	3.5	(3.28)		3.3	10.3	11.5	(2.65)	(1.37)	31.4
302	LRM rP.....	3.9	(4.07)		13.1	13.3	14.5	(2.50)	(1.27)	37.0
303	LRM aP....	3.5	(4.14)	No yields taken	13.1	11.8	14.8	(2.38)	(1.16)	43.8
304	LRM........	10.0	(2.51)		8.7	10.8	12.2	(2.07)	(1.03)	33.1
305	LRM rP.....	14.3	(2.82)		8.0	11.5	11.8	(2.33)	(1.39)	35.3
306	LRM aP....	13.8	(3.46)		7.1	10.7	11.5	(2.32)	(1.24)	28.9
307	L...........	10.7	(3.58)		6.6	14.7	9.1	(2.09)	(1.04)	26.1
		Clover[1]	Timothy[2]	Corn	Cowpeas	Wheat	Clover	Timothy	Corn	Cowpeas
401	LRM........			11.1	8.8			(1.65)	42.9	(1.15)
402	LRM rP.....			7.3	7.5			(2.30)	35.6	(1.55)
403	LRM aP....	No yields taken	No yields taken	7.1	8.0	Wheat winter-killed	No yields taken	(2.51)	31.5	(1.67)
404	LRM........			10.7	8.8			(2.25)	42.0	(1.70)
405	LRM rP.....			15.4	10.0			(2.46)	42.6	(1.87)
406	LRM aP....			12.0	7.7			(2.42)	35.6	(2.00)
407	L...........			10.0	9.2			(2.27)	25.1	(1.27)
		Timothy[1]	Corn	Cowpeas	Wheat	Clover	Timothy	Corn	Soybeans	Wheat
501	LRM........		23.2	3.4	12.5	(1.84)	(1.29)	28.7		7.5
502	LRM rP.....		30.0	4.2	14.2	(2.31)	(1.15)	31.7		9.0
503	LRM aP....	No yields taken	48.4	3.3	19.3	(3.00)	(1.65)	48.2	No yields taken	15.2
504	LRM........		43.2	4.4	17.0	(2.15)	(1.66)	42.1		15.2
505	LRM rP.....		39.6	4.2	17.5	(2.30)	(.88)	43.7		16.5
506	LRM aP....		46.6	4.8	18.5	(2.75)	(1.29)	48.0		15.0
507	L...........		38.4	5.6	11.7	(2.25)	(1.31)	56.9		7.7

[1]No soil treatment. [2]No manure.

TABLE 11.—NEW VIENNA FIELD: SUMMARY OF AVERAGE ANNUAL CROP YIELDS SHOWING DUPLICATE PLOTS, 1916-1924—Bushels (or tons) per acre

Crop	LRM		LRM rP		LRM aP		L
Corn (9 crops)	22.8	30.5	26.8	30.4	31.0	29.6	26.9
Cowpeas (7 crops)	11.0	10.7	11.9	10.5	10.4	9.5	10.4
Wheat (8 crops)	14.7	18.8	16.8	18.2	19.5	18.1	10.9
Clover (7 crops)	(2.53)	(2.28)	(2.76)	(2.50)	(2.86)	(2.59)	(1.99)
Timothy (6 crops)	(1.69)	(1.88)	(1.83)	(1.75)	(2.02)	(1.90)	(1.52)

represents, where washing from one plot to another is an inherent feature of the experiment, it is not surprising that the results of crop yields are unusually difficult, or even impossible, of interpretation. The only way of overcoming this kind of obstacle is thru ample repetition and replication whereby the experimental error due to plot variation can, to some extent, be determined. Unfortunately the opportunity for this kind of correction in the new Vienna field results is not very satisfactory on account of the meagre replication of plots.

The detailed results recorded in Table 10 are summarized in Table 11 in such manner as to show the average annual acre yields for the different kinds of crops, averaging the duplicate plots separately.

The discrepancies between duplicate plots so apparent in Table 10 are not wiped out in these summaries, the differences between duplicate plots representing the same treatment exceeding in many cases the differences between plots representing different treatments. Altho these experiments fail to answer definitely the questions they were intended to solve, there are some observations of interest to be made in looking over the data.

In the nine years of the experiments there were three seasons in which the corn crop was practically a failure, the different plots yielding from about 3 to 13 bushels an acre. On the other hand a good crop was produced in 1920, when the yield ranged from 44 to 57 bushels an acre. As to the treatments, it is impossible to conclude from the data which form of phosphate was the more effective on the corn crop, or indeed, whether the manurial treatment including the phosphates had any effect whatever.

There appears to have been only one very good crop of cowpeas (seed). This was in 1921, when the peas occupied the 200 series, and the treated plots produced about 26 to 33 bushels an acre. Owing to some errors known to have occurred in the harvesting, further discussion of the cowpeas is scarcely warranted.

With the exception of the crop of 1916, fair yields of wheat were obtained on the manured plots. The results show a considerable gain for the manurial treatment over limestone alone. No conclusions can be drawn as to effect of phosphate treatment on the wheat crop.

Good crops of clover were grown on these plots. There appears to have been a marked response to manurial treatment over limestone alone and possibly some response to phosphate fertilization, altho the latter increase is not very definite.

Some excellent crops of timothy were harvested and the average yields were good. The results indicate some benefit from the application of the more com-

plete treatments over limestone alone. Rock phosphate produced no significant effect according to average yields, but acid phosphate appears to have given a noticeable increase.

Altho, as stated above, the irregularities of the results preclude the drawing of specific conclusions concerning these various fertilizer treatments, it would appear, upon considering the results on all crops as a whole, to be doubtful whether phosphorus fertilization could be profitably practiced at all in a system of cropping such as was employed in these experiments.

THE ELIZABETHTOWN FIELD

The Elizabethtown experiment field was established by the University in 1917, in the unglaciated hilly section of southern Illinois. This field is located in Hardin county about two miles north of Elizabethtown. The soil is of loessial formation, the predominating type on this field being classified as Yellow Silt Loam. A detailed examination, however, shows the presence of some Yellow-Gray Silt Loam and also a very small patch of Stony Loam. The land is extremely rough in topography, the contour map showing a range in elevation of 42 feet on that part of the field occupied by the present plots. Erosion, therefore, is a serious problem. The field embraces about 32 acres, of which area about one-half is laid off into plots. There are four series of 10 fifth-acre plots each, included in a major rotation. Another series of 10 tenth-acre plots is devoted to another rotation, and in addition to these there are three other plots designated as A, B, and C, upon which a special phosphate test is being carried on.

The major rotation formerly included corn (with rye cover crop), soybeans, wheat, and sweet clover, but this was changed in 1923 to a rotation of corn, wheat, clover-timothy mixture, and wheat with sweet clover seeding on the residue plots. The plot treatments are indicated in the following table of results. The remarks made above in connection with the discussion of the New Vienna field on the difficulty of obtaining satisfactory experimental data on land of such rough topography, apply with equal pertinence to the Elizabethtown field. There are, however, certain effects standing out in such bold relief as to leave no doubt as to their significance. The results for the different crops are summarized in Table 12.

TABLE 12.—ELIZABETHTOWN FIELD: SUMMARY OF CROPS GROWN
Average Annual Yields, 1919-1924—Bushels or (tons) per acre

Soil treatment	Corn *6 crops*	Wheat following legumes *4 crops*	Wheat following corn *2 crops*	Timothy-clover mixture *2 crops*	Soybeans *3 crops*	Sweet clover seed *2 crops*
0	21.4	6.9	5.0	(0.00)	2.7	0.00
M	20.4	6.5	4.4	(0.00)	3.1	0.00
ML	33.5	11.1	10.2	(.90)	4.2	2.59
MLP	38.8	15.4	9.0	(1.45)	5.2	2.42
0	14.5	6.9	2.4	(0.00)	2.3	0.00
R	15.7	6.1	2.9	(0.00)	2.5	0.00
RL	31.8	11.6	4.9	(1.02)	4.3	1.99
RLP	41.3	15.7	5.2	(1.20)	5.0	1.74
RLPK	40.7	16.6	4.9	(1.44)	4.6	1.49
0	22.5	7.3	4.4	(0.00)	3.0	0.00

These results show extremely poor yields on the untreated land, with no improvement from the use of manure alone or residues alone. A sharp increase in yield, however, follows the application of limestone along with either manure or residues. Rock phosphate seems to have produced a beneficial effect on the corn, on the wheat following legumes, and on the timothy-clover mixture, in both the manure and the residues systems. The potassium treatment as applied in these experiments does not show sufficient benefit to cover the cost. The following general observations are of interest. The wheat following legumes has a much more favorable place in the rotation than the wheat following corn, which fact is manifested by the relative yields. Soybeans have not proved a very successful crop on this field. It is of interest to note that the residues system appears to be fully as effective in building up this soil as the manure system, but a rational system of farming might well include livestock, in which the manure as well as all available crop residues would be utilized for soil improvement.

The results from the minor rotation on Series 500 are too few to warrant consideration at this time.

On Plots A, B, and C a comparison of the two carriers of phosphorus, acid phosphate and rock phosphate, is under way. The acid phosphate is applied at the rate of 200 pounds an acre a year and the rock phosphate in double this quantity.

In a rotation of corn, cowpeas, and wheat, four crops of corn, three of cowpeas, and three of wheat can be compared at this time. It is of interest to note the results that thus far have been obtained, bearing in mind that the data are not sufficient to warrant drawing final conclusions as to which carrier of phosphorus will prove to be the more economical to use. Table 13 presents the crop yields from these comparative phosphate tests covering the period since the full soil treatment has been applied.

On the whole, the differences shown in the averages are relatively small, so that it may be said that after four years the data furnish no reliable indication as to which form of phosphate is the more effective in increasing crop yields.

TABLE 13.—ELIZABETHTOWN FIELD: COMPARATIVE TEST OF ACID PHOSPHATE AND ROCK PHOSPHATE

Annual Acre Yields of Crops Grown, 1921-1924—Bushels per acre

Year	Corn		Wheat		Cowpeas	
	Acid phosphate	Rock phosphate	Acid phosphate	Rock phosphate	Acid phosphate	Rock phosphate
1921......	28.8	28.6	....	....	9.2	7.8
1922......	34.4	32.0	3.2	9.8	12.5	4.7
1923......	32.2	46.8	18.6	14.3	10.5	9.2
1924......	54.6	59.2	13.3	8.8	....	....
Average...	37.5	41.7	11.7	11.0	10.7	9.5

THE UNIONVILLE FIELD

The Unionville experiment field is located in the extreme southern part of Illinois, in Massac county, immediately north of Unionville. This field is representative of a soil type classified tentatively as Yellow-Gray Silt Loam, altho it

should be noted that certain features of the soil profile are not altogether characteristic of the large prevailing body of soil mapped in southern Illinois under that type name. However, the results from this field are doubtless applicable to a considerable area of the land in Johnson county, and therefore a brief account of the experiments on the Unionville field are presented here.

This field is undulating in topography. It is thoroly tile-drained. The soil is strongly acid in reaction.

The field includes about 25 acres laid off into two general systems of plots under independent crop rotations. On the first four series, a rotation of corn, cowpeas, wheat, and cotton was started, but this was changed in 1922 to corn, rye, cowpeas, and wheat with sweet clover seeding on the residue plots. In 1924 the rotation program was again altered by replacing the rye with cotton. Table 14 indicates the various soil treatments included in the experiments and also summarizes the results obtained with each of the principal crops grown covering the time since full soil treatment has been in effect.

TABLE 14.—UNIONVILLE FIELD
Average Annual Yields of the Principal Crops, 1912-1924

Serial Plot No.	Soil treatment applied	Corn *10 crops*	Wheat *10 crops*	Cotton *10 crops*	Cowpeas[1]
		bu.	*bu.*	*lbs.*	*bu. or (tons)*
1	0	18.2	6.2	190	(.67)
2	M	24.0	8.5	315	(.80)
3	ML	31.4	14.6	501	(1.10)
4	MLP	32.0	18.3	522	(1.34)
5	0	16.8	6.6	154	3.5
6	R	19.8	7.9	138	3.9
7	RL	34.7	16.2	254	4.5
8	RLP	37.5	20.2	263	4.8
9	RLPK	42.6	21.8	459	6.0
10	0	17.1	7.0	162	(.66)

[1] Ten crops of hay on manure plots, 8 crops of seed on residue plots.

In looking over these results one may note the very poor yields on the untreated plots. Manure alone produces only a moderate improvement, and residues alone give on the whole very little, if any, benefit. Limestone, however, proves to be the critical factor in the improvement of this soil as evidenced by the sharp increases in crop yield where this material has been applied. The phosphorus plots show some increase for all crops, but the principal effect is on the wheat. Potassium, as applied in these experiments, likewise shows some increase in all crops, but more especially in the corn and in the cotton.

On the whole, the crop yields appear to be maintained just as well in the residues system as in the manure system, thus demonstrating the possibility of building up this soil without animal manure. For farm practice, however, the recommendation would be to make use of all available manure along with crop residues for supplying organic matter and nitrogen.

The work going on at present on the smaller series of plots of the Unionville field has as yet not been continued long enough to warrant summarizing at this time.

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4 Sangamon, 1912
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